ECONOMIC GEOLOGY

WITH WHICH IS INCORPORATED

THE AMERICAN GEOLOGIST

VOL. II APRIL–MAY, 1907 No. 3

THE COMPOSITION OF COALS.

FRANK F. GROUT.

INTRODUCTION.

The chemical nature of coal is rapidly becoming better known, and it occurrs to the writer that graphic representation of such reliable analyses as are at hand may suggest some interesting comparisons. The work of Mr. Iddings in presenting diagrams of rock analyses has proved of such value that the application of similar methods to coal analyses is presented in this paper with the hope that it may render clear some questions not heretofore perfectly understood and stimulate other workers to elaborate the material at their disposal.

An arrangement of this kind indicates that the coals of our new State of Oklahoma are of excellent quality, and this was one of the main objects of the study. The coal thus far tested by the U. S. Geological Survey shows Oklahoma coal to be above the average; yet the best coals have not been tested.

In this paper the work of other writers has been freely used, especially those of the U. S. Geological Survey and Professor S. W. Parr, of Illinois. Thanks are due to Professor Charles N. Gould and the University of Oklahoma for many kindnesses.

In the literature available the writer has found no attempts at the representation of coal by diagrams except those of Professor Parr[1] and a rough inaccurate diagram by Newberry to show the

[1] University of Illinois Studies, Vol. 1, No. 7.

process of alteration from cellulose to graphite. Professor Parr first made use of concentric circles one of which represented the ultimate and another the proximate analysis; and with a very little study, these gave a clear idea of the value of a coal. No attempt was made to arrange these in a multiple diagram. Recently the same author has made use of rectangles and the arcs of circles to make clear the composition of the volatile matter.[2]

CONSTRUCTION OF THE DIAGRAMS.

The value of a diagram depends first on the clearness and the readiness with which its meaning can be grasped and retained, and second, on the purpose of the diagram. In selecting a graphic representation of the four parts of a proximate analysis, the division of a circle by radii does not produce so clear and strong an impression as an arrangement of triangles. No arrangement can be found, in which lines (distances) being made in proportion to the analytical data, the areas will be readily intelligible. Equilateral triangles have therefore been used, such that the areas are proportional to the four constituents as shown by the proximate analysis. Fixed carbon is represented by a central white triangle, volatile matter by a black triangle placed just above; ash by a black triangle below to the left; moisture by a black triangle below and to the right (see Fig. 25). This makes a series of figures quite distinct in different parts of the coal series. By the diagram the character of the variation in proximate constituents can be seen at a glance, and the impression given is clearer than any obtained from a table of analyses.

To further show the chemical composition of the coals, it is instructive to arrange them in a multiple diagram, based on the ultimate analyses. The essential part of the coal is here considered to be the sum of carbon, hydrogen and oxygen. Nitrogen and sulphur, combined with carbon, are subordinate and not considered as affecting seriously the nature of the hydrocarbon compound. By thus using three elements, it becomes possible to represent the amounts of all by a single point in a triangular

[1] Illinois Geological Survey, Bull. 3, p. 33.

diagram (see Fig. 23). If at this point an individual diagram is constructed, all the analytical data can be seen at a glance, except the sulphur and nitrogen. The writer has made no attempt to show these points, though for practical purposes sulphur is of extreme importance, and it might be added to the individual diagram with no great complication.

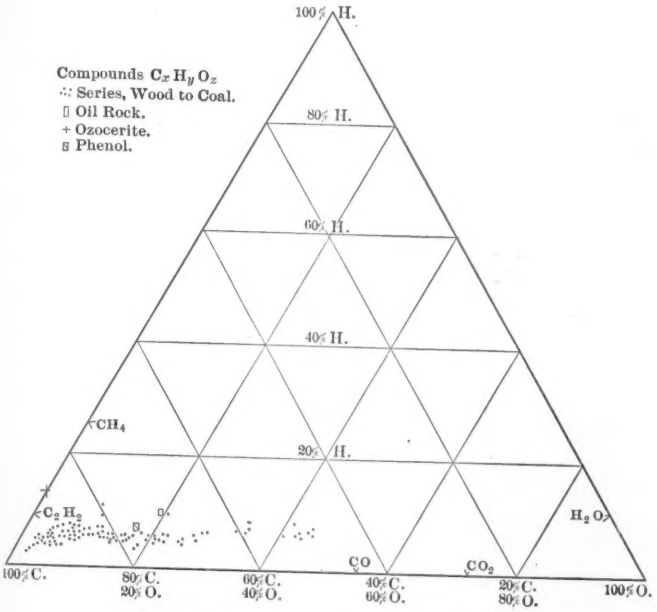


FIG. 23. Hydrocarbon compounds.

In arranging the multiple diagram all analyses are recalculated to 100 per cent. of carbon, hydrogen, and oxygen, leaving out the moisture, which cannot be part of the hydrocarbon. This makes the analyses comparable on a definite basis, besides making it possible to show the three elements by a single point.

Figure 23 shows the whole range of possible combinations of the three. It is not large enough for the introduction of in-

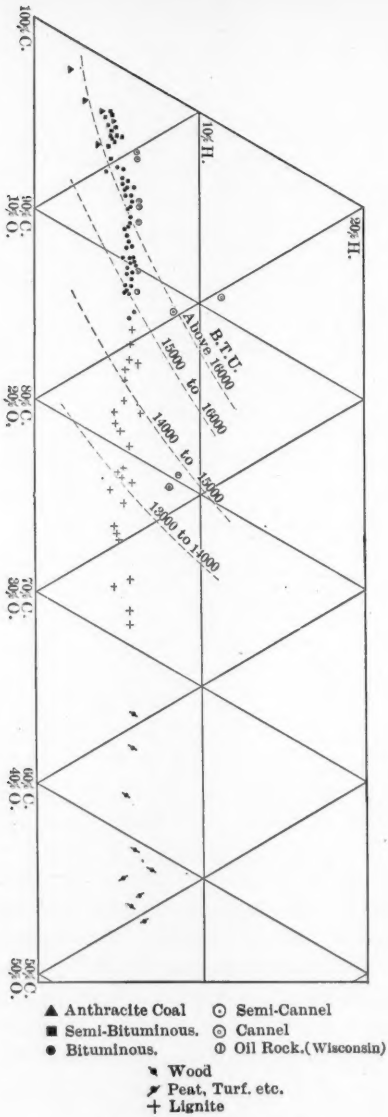


FIG. 24. The coal series.

dividual diagrams. Graphite and diamond lie at the lower left corner; hydrogen at the top; and oxygen at the lower right. Pure hydrocarbons lie on the line from 100 per cent. C to 100 per cent. H. The oxides of carbon lie on the base line. Water and hydrogen peroxide are on the right border. As plants form the source of so many hydrocarbon compounds, it is of interest to note the position of cellulose—just below the center. Other plant products have rather different composition and the variation is suggested as the reason for some varieties of coal. Most of the dots represent the coal series; but some common compounds lie in the same position in the series; as, for example, phenol, one of the products of the distillation of coal.[1]

Fig. 24 shows the coal series enlarged from Fig. 23. Coals of different type by reputation in the market are shown by different symbols.

In Fig. 25 some scattered examples from the series are shown in the combined diagram. The whole series of available reliable analyses could not be clearly presented in this form on a sheet much smaller than four feet long, but makes a very instructive diagram.

Fig. 26 contains a result of the study of the preceding and will be discussed below.

PURPOSE.

The main purpose is, of course, the simple graphical comparison of the chemical analyses of coals in such a form that one may see at a glance the relation of a sample to the whole series, and the common range of variation. The gradual nature of the variation in all directions, the fact that there is no break in the series from wood to graphite, from lignite to cannel, and the interesting nature of the extremes of the series, are clearly brought out, as is the fact that most of the analyses available are of bituminous coals. In this connection the diagrams furnish good graphical argument as to the origin of coal.

[1] The construction would have been simpler, but the diagram less clear, if two of the constituents had been plotted between rectangular coödinates. When two are thus shown, the third could always be found, as 100 per cent. minus the sum of the two.

Fig. 25. Coal diagrams.

The gradual chemical change has long been noted, but the diagrams show it at a glance.

Some further points were brought out, though not altogether responsible for the construction of the diagram, such *e. g.*, as the constancy of the per cent. of hydrogen. This may have some bearing on the reactions in the metamorphism, oxygen being the heaviest loser. The average per cent. of hydrogen from wood, over to semi-bituminous coal is 5.64 ± 60 the average error being 0.30 per cent. and smaller if confined to the bituminous alone. In a single coal basin or single seam, the error might be reduced. In the large number of Illinois coals (21) tested at St. Louis, the average is 5.67 per cent., with an average error of 0.22 per cent. The uselessness of any further calculation of available hydrogen is apparent.[1]

The final value of the figures is the light they throw on the matter of the classification of coals.

ANALYSES USED.

The larger part of these are from the results of the U. S. Geological Survey. All the analyses of coals, tests of which are reported in Professional Paper No. 48, are used; and a few from Bulletin 290, where they would fill any gap in the series. These are taken as representing the most modern and exact results possible, though there is evidence that no compensation has been made for the error due to the oxidation of the iron of pyrite which is weighed in ash as Fe_2O_3 and may affect the figure for oxygen by as much as 2 per cent. The lignite analyses published by E. T. Dumble[2] have been quite freely used. The report of Michigan coal, by Lane[3] was also used. Some analyses of cannel were taken from Thomas's book "Coal Mine Gases and Ventilation."

[1] These errors are less than 4 per cent. of the total hydrogen. Professor Parr's elaborate calculation in Bull. 3 of Illinois Geological Survey gives results that vary by 5 per cent. in Illinois coals alone and much higher in some cases.

[2] Geol. Surv. of Tex. Rep. on Brown Coals and Lignites of Texas.

[3] Michigan Geological Survey, 8, 110.

In Fig. 2 an attempt was made to enclose all coals of similar fuel value in groups by dotted lines, using, for the purpose, the fuel value of ash- and water-free coal. The highest values were not for the last stage in the metamorphism. This brings up a question in classification. Which should be given first place—the coal of best fuel value, or the most metamorphosed coal? Inasmuch as it is commonly known that anthracite has not so high a fuel value as some other coals, it seems unnecessary to place it with others of so different a character as those of similar fuel value. It was noted at once, however, that the fuel value of the hydrocarbon of limited fields is not constant as some have attempted to show.[1] If any such relation exists between hydrocarbon and fuel value, the field must be more restricted than the "Oklahoma field" or "the Illinois field" where variations reach nearly 5 per cent. Professor Parr[2] in his calculation of "true fuel" and "gross coal index" implies that the fuel value of $C + (H - 0/8)$ can be calculated, but this is just as uncertain, and seems to depend on the method of combination of the hydrocarbon.[3]

The purpose of the diagrams has been outlined and it is thought that they will be quite self-explanatory. The bearing of the figures on the classification of coals, however, needs some detailed study. The material of the analyses seems to be quite similar to that published long ago, but as recent writers on classification seem to have lost sight of several facts, the diagrams may help to set things right. Misconceptions have arisen which might have been avoided by a study of the literature, even before the large amount of work by the U. S. Geological Survey.

[1] *Jour. Am. Chem. Soc.*, Vol. XXVIII., p. 1430.

[2] Lane, Michigan Geol. Survey, VIII., p. 87.

[3] A rough attempt was also made to group all good coking coals in a manner similar to that used to group coals of similar fuel value. But there are too many variables, and the coking is not dependant entirely on the hydrocarbon, but also on the ash, and the method of coking.

CLASSIFICATION.

First, it must be evident that there are no natural groups, and any group designated must be limited quite arbitrarily. Second, as it is the general market which will eventually decide whether any classification suits its needs, we may consider in a word, the commercial classification. This is based on the physical action of a coal in the fire. Griffith[1] even questions the use of fuel ratios in proof of anthracite, saying that these coals, and only these, burn *without smoke*. And Dr. H. F. Bain suggests that the only proof of a lignite is, that if charged into a locomotive fire-box, it all goes out the stack. These properties are variable in any coal and determination depends too largely on the personal factor. Even the U. S. Geological Survey call their sample Montana No. 1 a coal in one place and a lignite in another. Moreover, there is a complete gradation between the classes. Dumble mentions[2] several other physical properties, but none are more definite. Such are the commercial methods and it would be quite surprising if any scientific method could possibly be made to conform to this determination.

Turning to chemical methods we find various suggestions, quite recently in particular. The early fuel ratio[3] disagrees with the commercial, too seriously to be satisfactory in discussing the lignite series. Collier and Hayes,[4] after finding that geological age would not distinguish lignites, let the matter rest with fuel ratio and water, both being involved. W. D. Smith follows this plan, letting more than 10 per cent. moisture distinguish lignites.[5] He refers to Grüner as using a ratio $O + N$; H, which is similar to some mentioned below, but quite complex. Both Dumble[6] and recently Campbell[7] have shown that moisture is not a safe distinction for lignites. Campbell then discussed

[1] *Mining Magazine*, XIII., p. 214.
[2] *Loc. cit.*, p. 48.
[3] Frazer, *Trans. A. I. M. E.*, VI.
[4] U. S. Geol. Survey, Bull. 218.
[5] Bull. 5, Mining Bureau, p. 44. Dept. of Int., Manila.
[6] *Loc. cit.*
[7] U. S. G. S. Professional Paper 48, p. 157.

the results of tests of coal at St. Louis, using for his arrangements, fuel ratio, fixed carbon, carbon, hydrogen, and the ratio of carbon to hydrogen. In most of this work the hydrogen of moisture is included. This seems absurd. The order of arrangement is entirely changed by omitting it. The carbon-hydrogen ratio which he finds most satisfactory fails utterly and the reason can be seen by a glance at figure 24. Although the hydrogen of lignites and bituminous coal is not much different, the range in each amounts to nearly a third of the total. When the per cent. of carbon is divided by this variable, it is to be expected that coals of similar quality will give quotients varying by 25 per cent. or more. Parr remarks that the use of hydrogen is "illogical" without explanation. But if Mr. Campbell had excluded both moisture and ash, in his arrangement, based on total carbon, he would have found an excellent separation of coal and lignite. This is also seen in a glance at Fig. 24. In spite of the complete gradation from wood to graphite, it is possible to draw a line on the diagram, such that no coal will be on the right of it, and no lignite on the left. Still more remarkable, the line may be inclined so as to represent a per cent. of carbon or, in the other direction, so that it represents a certain per cent. of oxygen. More complete lists of analyses may develop some cases where a coal known in the market as bituminous, will fall on the lignite side, or *vice versa,* but *none have yet come to our notice.* The fact that both carbon and oxygen are capable of distinguishing lignites, is a result of the comparative constancy of hydrogen.

The use of oxygen in this way is not at all new, though the recent writers have not seemed to be aware of it. Dana's Mineralogy informs us that bituminous coal contains 5 to 15 per cent. oxygen (rarely 16 or 17), ash excluded, while lignites, *dry,* contain 20 to 36 per cent. F. P. Dewey[1] says brown coal is one of the subdivisions of bituminous coal, "but more highly oxygenated than any of the other coals, containing 15 to 30 per cent. oxygen." Dumble[2] refers to some work by Cappacci

[1] Bull. 42, Smithsonian Institute.

[2] *Loc. cit.,* p. 33; 1892.

on Italian lignites, which seems very good. Dumble gives the following, though he does not use it except as a distinction for lignites.

$$C:(H+O) = 1.0 \text{ in wood.}$$
$$C:(H+O) = 2.3 \text{ in lignite.}$$
$$C:(H+O) = 5.6 \text{ in bituminous coal.}$$
$$C:(H+O) = 19.0 \text{ in anthracite.}$$

In spite of these references (where oxygen is used), which are available to the U. S. Geological Survey, Campbell tries only carbon, hydrogen, and fuel value and says these are "all the elements upon which a classification can logically be based." Carbon would be good, if he had not included moisture, but if he did not find it so, oxygen was as good as in years past. Professor Parr makes much of "inert volatile matter," saying its only recognition thus far seems to be in Dulong's formula. It is the well-known oxygen which determines the amount in inert volatile which is practically no more nor less than 9/8 oxygen, or water. He seems to consider it a new distinction, but if oxygen is distinctive 9/8 oxygen should be equally good, only more complicated. An effort seems to have been made to let a single ratio determine the place of a coal in the classification. But the diagrams show the difficulty. Coal varies in three directions, and at least two independent variables are needed to classify it. A single ratio would always place cannel coals with others of very different quality. Analyses of cannel are scarce. But the writer's own work on Illinois cannel[1] and again on some Brazilian turf, for Dr. I. C. White, fill in some gaps in that part of the series. Professor Parr's is the only classification yet proposed which can furnish a place for cannel. If he would introduce between his groups C and D a group

"E . . . Cannel $\begin{cases} VC \times 100/C = 40 \text{ per cent. up} \\ \text{inert volatile 5 to 10 per cent.,"} \end{cases}$

[1] Credit should be given Doctor Bain and the Illinois Geol. Survey for whom the work was done.

it might well represent cannel,[1] but simpler relations are easily found.

THE LOGICAL CLASSIFICATION.

Both the proximate and ultimate analysis give data from which variations in coal may be noted, but in recent study it is becoming ever more clear that the former alone is not sufficient in all cases. The use of the ultimate analysis alone was not a success as tried by Mr. Campbell. Professor Parr uses both proximate and ultimate with some complication, the value of which may be questioned. Two main points should be considered in selecting data for classification. First, the results *should distinguish* the groups and show a considerable range beween the groups. Second, the data should be simple and easy and accurate of determination. Professor Parr's "inert volatile" is complex, difficult, and inaccurate. His new ratio does no better than the old fuel ratio. To emphasize this point let us repeat, the simplest accurate way to relegate a coal to the group "anthracite," for example, is the one to use; for when we say it is an anthracite no one thinks of a coal with any other properties than those of anthracite. There are many points which would determine it. The diagrams show carbon high, hydrogen low, oxygen low; hence, carbon-hydrogen ratio high, carbon-oxygen ratio high; also, fixed carbon, high, volatile matter low, fuel ratio high, etc., etc. When one says anthracite, all these things are necessarily included. The determination of the fact that it is anthracite does not need any *certain one* of the points any more than the public need to be told that anthracite does not smoke. It is understood. Similarly, with the other groups. The simplest accurate points make the best classification.

Fuel ratios are simple, but do not distinguish cannel, lignite, and bituminous coals. It is necessary to introduce some data from the ultimate analysis. If it is desirable to base the whole thing on ultimate analysis, this could be done by the use of the points above suggested for the distinction of anthracite, and some other, like carbon or oxygen, for the distinction of lignites. But this restriction to the ultimate, does not seem necessary. The proximate really gives the best distinction for high-carbon coals.

[1] *Jour. Am. Chem. Soc.*, XXVIII., p. 1429.

What point, then shall we select as the distinction for lignites? There is a possibility that it may be found easier to determine total carbon in a coal without a complete analysis. Numerous pieces of apparatus have been put on the market in the last few years for carbon estimation, without reference to other constituents, and the writer would recommend carbon, if accurate, as a basis for the distinction. Parr uses this carbon estimation to calculate "inert volatile" by a method which varies as his study of coal proceeds. He does not claim great accuracy for the determination and, as already mentioned, carbon itself is a good and sufficient distinction; certainly, more accurate than a figure estimated from this and a couple of other variables. Oxygen would be as good if a complete ultimate analysis is at hand (see Fig. 24). The carbon-hydrogen ratio fails. Taken in connection with fuel ratio, total carbon makes a satisfactory classification.

But now it is time to question whether the fuel ratio is best for high carbon coals. It is so well known that it may be useless to discard it. However, it seemed simpler to use the per cent. of fixed carbon in the hydrocarbon. The two variables are then of the same type; viz., fixed carbon of the pure coal, and total carbon of the pure coal. To avoid the ultimate analysis, one must consider the pure coal as the sum of fixed carbon and volatile matter instead of the sum of carbon, oxygen, and hydrogen. This does not alter the arrangement of coals except in case of New Mexico coals, and one sample from Iowa. These are near the border line.[1] This is the classification presented at the close. It is to be noted that each figure for a per cent. of fixed carbon might be replaced by a certain fuel ratio, for the volatile matter is 100 per cent. minus the fixed carbon, and the

$$\text{fuel ratio, therefore} = \frac{\text{Fixed Carbon.}}{100 - \text{Fixed Carbon.}}$$

In this discussion the matter of simplicity has predominated.

[1] Campbell describes the New Mexico samples as coal, in the field, but classifies them as lignites, as they seem to be. One Iowa coal has the same carbon-hydrogen ratio, however.

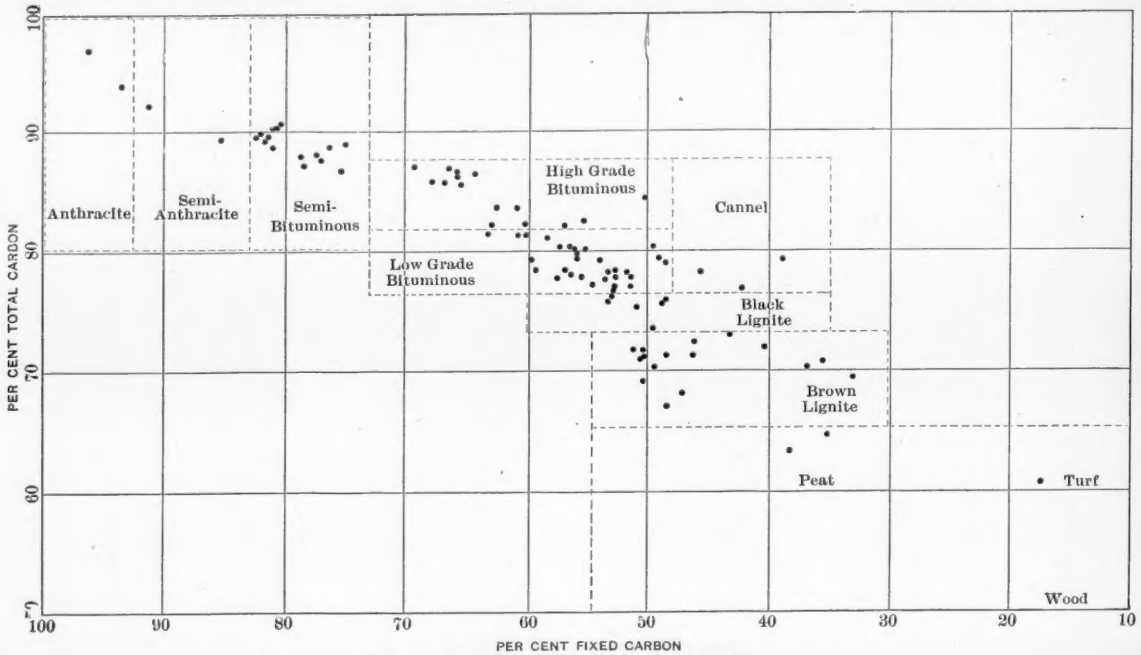


FIG. 26. Diagram of proposed classification.

The range is equally satisfactory; fixed carbon varying from 99 to 9; while total carbon varies from 99 to 50. Oxygen which has been used shows a very good range, but it is determined "by difference" and cannot be better. No other factors show a greater range. Then why offer the more confusing or more inaccurate ones?

The classification at the end of this paper is shown diagrammatically in Fig. 26. Bituminous coals are divided into two groups on the basis of total carbon. They might well be again divided on the basis of fixed carbon, as those at the right of the group approach cannel coals, and are already known in the market as "semi-cannels." These include some from Michigan and Missouri. A line along 51 per cent. fixed carbon would separate them into a small group, the relation of which to cannel is apparent. The groups known as peat, turf, and oil-rock, overlap each other and wood, probably on account of the variable nature of wood. The brown lignites are well distinguished from black.[1]

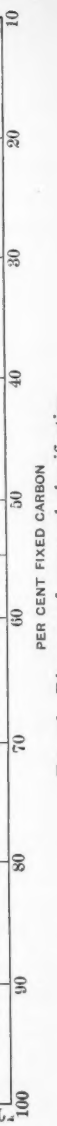


Fig. 26. Diagram of proposed classification.

In conclusion two points should be emphasized. First, the well-known fuel ratio can be substituted, point for point, in place of the fixed carbon of the classification, making no change in the result. This means that the present classification is used as a basis and the addition of a simple carbon determination makes it complete.

Second, the arrangement may seem scientific rather than practical, but can easily be translated into an everyday meaning. The writer is certain that if it be said that a coal is "cannel because it has 40 per cent. fixed carbon and 80 per cent. total carbon in the pure coal," no one will think of coal of any other properties than those of cannel. It is completely defined as to fuel ratio, carbon-hydrogen ratio, etc. Similarly with all the groups presented.

It may be that at some time the limits assigned these groups may be somewhat altered, but they now seem quite definite and well-fixed.

[1] Since this line between black and brown is so sharp, and that between black lignite and coal so ill-defined, it might be well to class the black lignites as low-grade bituminous; they are really a small group. Still they have physical properties of other lignites, like decrepitation.

SUMMARY.

All the chemical constituents of coals (except nitrogen and sulphur, which might be added) are shown graphically in a multiple diagram to indicate the general relationships of the coal series.

The character of the variation is well displayed and the variation is not a linear one, as the series ranges in two directions.

The bearing of the diagrams on the classification of coals is mentioned.

The logical classification is sought and a sample is here presented. The data used are the fixed carbon in pure coal and total carbon in pure coal; *i. e.*, ash- and water-free coal (see Fig. 26).

CLASSIFICATION OF COALS.

Graphite	Fixed carbon over 99 per cent.
Anthracite	Fixed carbon over 93 per cent.
Semi-Anthracite	Fixed carbon 83 per cent. to 93 per cent.
Semi-Bituminous	Fixed carbon .73 per cent. to .83 per cent.
Bituminous:	
High Grade	Fixed carbon 48 per cent. to 73 per cent. Total carbon 82 per cent. to 88 per cent.
Low Grade	Fixed carbon 48 per cent. to 73 per cent. Total carbon 76.2 per cent. to 82 per cent.
Cannel	Fixed carbon 35 per cent. to 48 per cent. Total carbon 76.2 per cent. to 88 per cent.
Black Lignite	Fixed carbon 35 per cent. to 60 per cent. Total carbon 73.6 per cent. to 76.2 per cent.
Brown Lignite	Fixed carbon 30 per cent. to 55 per cent. Total carbon 65 per cent. to 73.6 per cent.
Peat and Turf	Fixed carbon below 55 per cent. Total carbon below 65 per cent.
Wood	

As an example of the calculation, one will suffice,[1] Indian Territory No. 2. The analysis is:

Moisture	1.70 per cent.
Volatile matter	37.19 per cent.
Fixed carbon	49.79 per cent.
Ash	11.32 per cent.
Total carbon	71.49 per cent.

The pure coal is, therefore, 86.98 per cent. and in the pure coal, fixed carbon amounts to 57.25 per cent. while total carbon

[1] U. S. Geol. Survey Prof. Paper No. 48, p. 215.

is 82.17 per cent. The figure for fixed carbon might place it with high or low grade bituminous coal, or black lignite, but the figure for total carbon places it with high-grade bituminous coal. A few applications to domestic coals are given below:

APPLICATION OF CLASSIFICATION TO COALS OF UNITED STATES.

Name of Sample.	Locality.	Fixed Carbon (in pure coal).	Total Carbon (in pure coal).
Anthracite.			
Pennsylvania No. 3.	Scranton.	91.09	92.18
Semi-Anthracite.			
Arkansas No. 5.	Spadra bed.	85.18	89.34
Semi-Bituminous.			
West Virginia No. 12.	Pocahontas bed.	80.47	90.48
West Virginia No. 10.	Pocahontas bed.	80.15	90.70
Arkansas No. 1.	Huntington bed.	79.26	88.05
Arkansas No. 3.	Huntington bed.	79.21	89.43
West Virginia No. 6.	New River field.	76.94	88.70
Bituminous High Grade.			
West Virginia No. 8.	Kanawha field.	64.72	86.50
West Virginia No. 4.	Upper Freeport bed.	68.29	86.23
Alabama No. 1.	Warrior field.	62.59	84.10
Kentucky No. 1.	Eastern field.	60.06	83.62
West Virginia No. 2.	Pittsburg bed.	55.71	82.13
Illinois No. 3.	Marion County.	63.26	81.62
Indian Territory No. 1.	Henryetta bed.	58.36	81.43
Bituminous Low Grade.			
Indiana No. 1.	Sullivan County.	55.04	80.23
Indian Territory No. 3.	McAlester bed.	56.08	79.96
Kansas No. 2.	Weir-Pittsburg bed.	59.91	79.42
Iowa No. 1.	Wapello County.	59.42	78.95
New Mexico No. 2.	Gallup field.	52.07	78.06
Kansas No. 4.	Atchison field.	55.85	77.59
Illinois No. 1.	Belleville field.	51.35	77.52
Missouri No. 3.	Putnam County.	54.93	76.97
Indian Territory No. 5.	McAlester bed.	54.08	76.47
Black Lignites.			
Colorado No. 1.	Boulder field.	53.69	76.15
Iowa No. 3 (coal)	Polk County.	48.77	75.82
Montana No. 1.	Red Lodge.	53.97	75.77
Brown Lignites.			
Wyoming No. 2.	Cambria field.	49.86	73.71
Texas No. 2.	Wood County.	50.43	72.06
North Dakota No. 2.	Williston field.	51.56	72.02

COPPER DEPOSITS OF THE NEW JERSEY TRIASSIC.[1]

J. VOLNEY LEWIS.

HISTORY.

About 190 years ago copper mining was first essayed at the old Schuyler mine, near Arlington, New Jersey, the first of its kind in the American colonies. Scarcely a decade has since elapsed without more or less endeavor to establish the industry in New Jersey. Considerable sums of money and much labor have been expended, many thousand feet of underground workings have been opened in the central part of the Triassic belt, and costly reduction plants have been erected; but as yet none of these numerous enterprises has proven permanently successful.

Several localities have produced ore for shipment and smelters have been operated at some half a dozen places; but only the pioneer Schuyler mine seems to have achieved any considerable degree of success at any time, and the later history of this, like the others, has been a succession of disappointments. True, in the early days, it was often difficult or even impossible to drain the workings to more than a very shallow depth; and concentration, beyond crude hand cobbing, was expensive and inefficient; while in later times efforts have often been ill-directed and money wasted on useless appliances.

In fact it may reasonably be questioned whether, in any case, the average grade of available ore has been satisfactorily established, and it is quite certain that nowhere has the existence of any great body of ore yet been demonstrated. This is the more to be regretted because in some instances considerable deposits may reasonably be expected, and, with proper direction,

[1] This paper is based on data gathered in connection with an investigation of the Triassic (Newark) trap rocks of New Jersey for the State Geological Survey, and I am indebted to Dr. Henry B. Kümmel, State Geologist, for permission to publish it here.

the money already expended would long ago have determined this question.

Whether or not any of these mines shall ever again become commercially profitable, they constitute an exceedingly interesting example of a class of ore-deposits, and are of considerable importance in the investigation of the principles of their origin. It is hoped that this discussion may contribute something toward the advancement of this branch of applied geology by directing the attention of geologists to these easily accessible deposits and by stimulating further study and discussion.

AREA AND STRUCTURE OF THE TRIASSIC.

Area.—Of the long narrow belt of Triassic extending from southern New York into northern Virginia, a little more than one fourth lies within the state of New Jersey, occupying about one sixth of the total area of the state. From Trenton up the Delaware River the belt is 32 miles wide; from the Hudson River westward along the New York state boundary it has narrowed to one half this width. Its topography is gently undulating to hilly, with the exception of a number of prominent ridges, locally called mountains, due to the outcropping edges of thick diabasic sheets commonly known as trap.

The Rocks.—The most characteristic sedimentary rocks are fine grained red shales. But there are also heavy bedded sandstones at various levels, chiefly in the lower parts, and coarse conglomerates occur at the base and at various intermediate horizons. In the southwest there are areas of heavy black argillites, with gray and green flagstones and occasional calcareous layers. The traps are both extrusive and intrusive; the former form broad thick sheets chiefly in the area of the Watchung Mountains, the latter heavy sills and dikes, appearing prominently in the Palisades of the northeast and in Rocky Hill, Sourland Mountain, and various smaller masses in the southwest. It has been shown[1] that there were probably four suc-

[1] J. Volney Lewis, "The Structure and Correlation of the Newark Trap Rocks of New Jersey," Geol. Society of America, New York meeting, December, 1906.

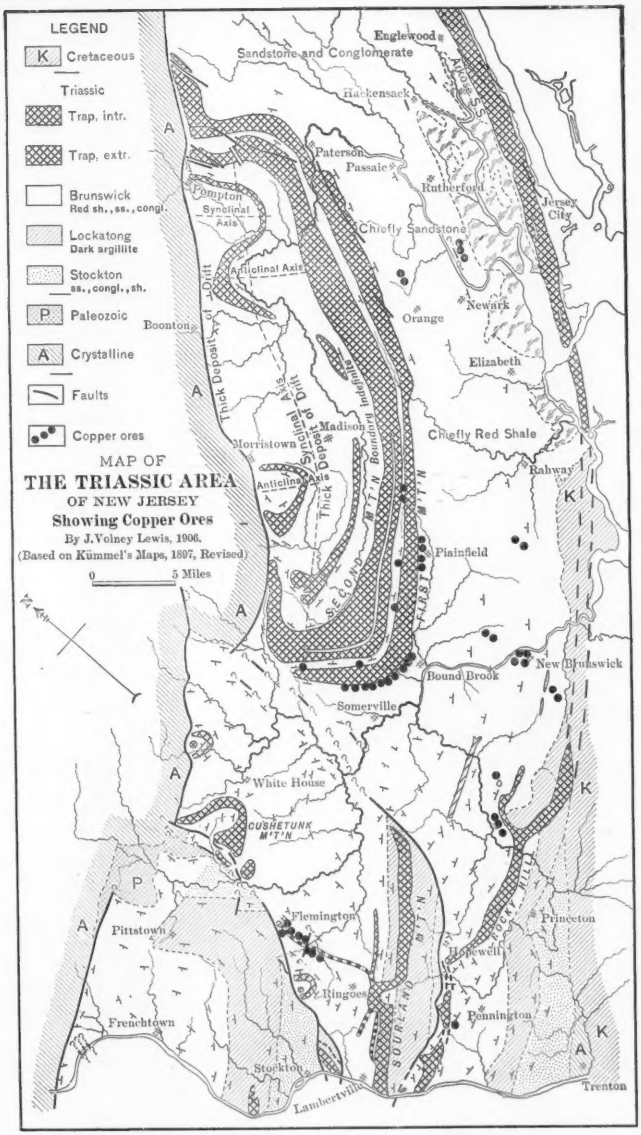
cessive periods of eruption, the Second Watchung sheet being regarded as double, followed by the intrusion of a great sill which now outcrops in Rocky Hill, Sourland Mountain, etc., disconnected by the Cretaceous covering in the southeast and faulting in the southwest. (See map, Pl. 1.) The traps occupy more than one tenth of the Triassic area of the state.

Dip and Strike.—The prevailing northeast-southwest trend of the ridges is due to the subsequent tilting of the strata toward the northwest. The dips are quite uniformly 10 to 20 degrees, with rare local exceptions. The structure is quite regular and simple along the southeastern side, with increasing complexity toward the crystalline Highlands on the northwest. The recurved Watchung ridges outline a shallow, platter-shaped syncline which incloses the upper basin of the Passaic drainage. This is rendered somewhat iregular by smaller cross-flexures, and the northwestern side has been sheared off by a fault. The spoon-shaped eastern end of a larger syncline lies east of Frenchtown, and there are a few other small local wrinklings and wavelike undulations of the strata.

Faults.—The great Hopewell and Flemington faults of the southwest, each of which has displaced the strata many thousand feet, and the three faults along the northwestern boundary of the Triassic have been described by Kümmel.[1] There are also numerous smaller faults, mostly, like these, with a north-south or a northeast-southwest strike and nearly vertical; but apart from the trap rocks few of these can be recognized, except where seen in fresh exposures, on account of the monotonous uniformity of the shales. In railway cuts and quarries in the traps these fissures are nearly always abundantly found, with displacement varying from almost nothing to several hundred feet. Many of the larger ones have produced pronounced topographic effects on the trap outcrops.

Almost without exception these faults, great and small, have the downthrow on the east; hence the great Hopewell and Flem-

[1] Annual Report of the State Geologist of New Jersey for 1896, p. 78; 1897, p. 107.



THE TRIASSIC AREA OF NEW JERSEY.

ington faults have caused a three-fold repetition of the strata and have at least doubled the width of outcrop of the Triassic along the Delaware River. The minor faults have doubtless had similar effects on a smaller scale throughout the area.

COPPER IN THE TRAP ROCKS.

Chalcopyrite is often visible in the traps, both in the fresh rock and in the veins of secondary minerals resulting from their alteration. Native copper also occurs in the midst of the trap in the quarries at Chimney Rock (near Bound Brook) and near its contact with the underlying shales in the American mine north of Somerville. Green stains of chrysocolla and malachite are of common occurrence in the joints near weathered outcrops.

The fresh traps also carry copper as a constituent of the pyroxenes. Numerous assays of the extrusive trap of First Mountain[1] yielded an average of one fortieth of one per cent. of copper; and a determination recently made in the laboratory of the State Survey showed nearly one fiftieth (0.019) of one per cent. in pyroxenes from the intrusive trap of Rocky Hill.[2]

COPPER IN THE SEDIMENTARY ROCKS.

All mining and prospecting have been confined to the sedimentary rocks, where the shales and sandstones sometimes carry disseminated grains and irregular masses of copper ores, with occasional vein-like aggregates and impregnated fault-breccias. Seventy years ago Professor Rogers[3] showed "that the ore does not exist in any instance in the shape of a true vein," but "has been injected into the body of the red shale and sandstone," of the regular stratified series.

The Copper-bearing Minerals.—The copper occurs chiefly in the form of chalcocite (or glance) and native copper. Associated with these are usually varying amounts of secondary minerals resulting from their alteration. The chief of these

[1] Annual Report of the State Geologist of New Jersey for 1902, p. 136.

[2] J. Volney Lewis, "The Newark (Triassic) Copper Ores of New Jersey," Annual Report of the State Geologist of New Jersey for 1906.

[3] Report of the Geol. Survey of New Jersey, Henry D. Rogers, Philadelphia, 1836, pp. 167, 169.

is chrysocolla, and there are smaller quantities of cuprite, malachite, and azurite. The greenish secondary mineral has usually been reported indiscriminately as malachite, whereas it is found to be chiefly chrysocolla, the silicate, in every case, with only minor amounts of the green carbonate, and rarely the blue.

Modes of Occurrence.—The ores occur in four distinct types of association, two with and two without accompanying intrusive trap, as follows:

I. With intrusive trap rocks:

1. In metamorphic, or "baked," sediments accompanying the trap; as in the Rocky Hill (Griggstown) mine.

2. In unaltered sediments intersected by dikes; as in the Arlington (Schuyler) and Flemington mines.

II. Without associated intrusives:

3. In unaltered or very slightly altered sediments with extrusive trap; as at numerous localities along First Mountain near Pluckamin, Somerville, Bound Brook, and Plainfield.

4. In unaltered strata entirely apart from known trap masses of any kind; as at New Brunswick, Glen Ridge, and Newtown.

ORE-DEPOSITS NEAR INTRUSIVE TRAP.

The Rocky Hill (Griggstown) Mine.—This mine is a mile south of Griggstown and two miles northeast of Rocky Hill, on the western slope of a ridge. The crest of the ridge is an offshoot of the intrusive sill of Rocky Hill intruded approximately conformable to the strata, which here strike N. 45° E. and dip from 10° to 20° NW. Approaching the trap the normal red color of the shale changes through purple to gray and nearly black, with corresponding increase in hardness in the intensely metamorphosed zone near the contact. This zone of hard, blackish hornfels is more than 100 feet thick and is often thickly set with rounded and rectangular masses of chlorite, ranging from minute specks to more than an inch in diameter. Apophyses of the underlying sill are encountered in the mine and appear as oval and irregular outcrops in the vicinity.

The essential ore is glance, with occasionally a little chalcopyrite and small amounts of secondary chrysocolla, malachite,

and cuprite. Associated with these are frequently found tourmaline, magnetite, hematite, epidote, and occasional feldspar crystals, besides the chlorite nodules described above. Weed[1] reported native copper, tenorite, and bornite, but a careful search of the mine, the old dumps, and old collections failed to verify any of these. Native copper, however, is to be expected; but the microscope shows chalcocite often so intimately mingled with magnetite and hematite as to be easily mistaken for bornite by the ordinary tests, and some of the soft black masses of magnetite, hematite, or tourmaline have doubtless been mistaken for tenorite.

Chalcocite, the original and essential ore, occurs in fissures and brecciated zones in the flinty hornfels, which is sometimes bleached white in the vicinity of the ore. The ore penetrates microscopic cracks in the rock and is sometimes found in the chlorite nodules with which it is studded. A thrust-plane parallel to the bedding also carries three inches to a foot or more of soft, clay-like material impregnated with ore.

The Arlington (Schuyler) Mine.—The mine is a mile northeast of Arlington and eight miles west of New York City. As at Rocky Hill, the ore is chalcocite, or glance, with chrysocolla, a little malachite, and occasionally azurite, cuprite, and native copper. It occurs, however, in unaltered, gray arkosic sandstone, which is penetrated by thin trap sheets and irregular branching dikes, and overlain by red shale. The ore occurs in the sandstone near the trap sheets and dikes, in branching veins and seams and in occasional fault-breccias of both sandstone and trap. The larger masses of chalcocite exhibit prominent cleavage faces and are sometimes thickly filled with quartz grains and minute reddish crystals of feldspar. The sandstone is also widely impregnated with chrysocolla and occasional disseminated grains of chalcocite. There are two layers of sandstone, the lower about 10 feet thick and the upper about 12 feet, separated by about one foot of shale. The dip is 9 degrees west.

"Over wide areas in this mine the surface of this sheet (of intrusive trap) is smooth and conformable to the gently dipping

[1] Bulletin U. S. Geological Survey No. 225, p. 188.

sandstone, but there are irregularities in which the strata are crossed for a few feet, and the sheet also sends several offshoots up into the sandstone. It is stated that the diabase surface was followed westward for half a mile in the mining operations, and that at one point it is traversed by a fault of considerable amount."[1] Figure 27 shows similar relations found in a quarry three fourths of a mile south of the Arlington mine.

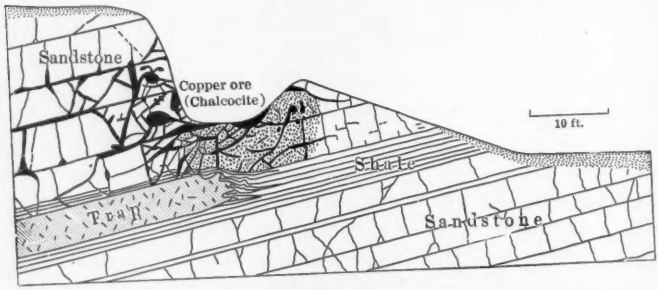


FIG. 27. Copper seams and impregnations, West Lake's quarry, Arlington N. J., three quarters of a mile south of the Arlington (Schuyler) Mine. (After Darton Bull. U. S. G. S. No. 67, Fig. 33.)

The Flemington Mine.—The mine is in the southwestern part of the town of Flemington, and the ore is in partly altered brownish red and purplish shales, which are intersected by trap dikes. As at Arlington and Rocky Hill, the ore is chiefly chalcocite with occasional grains of chalcopyrite, and the usual secondary minerals, chrysocolla, cuprite, and malachite, associated with calcite. Geologically the conditions are closely similar to those at Arlington. The ores are found two miles southward from Flemington, along the course of the dikes, to Copper Hill.

ORE DEPOSITS NOT ASSOCIATED WITH INTRUSIVES.

The Somerville (American) Mine.—The location is three miles north of Somerville, on the steep southwestern escarpment of First Mountain. The ore is essentially native copper, altered above the depth of 100 feet (600 feet on the slope) to cuprite,

[1] N. H. Darton, Folio U. S. Geological Survey No. 83, p. 10.

chrysocolla, and malachite. Occasional grains of chalcocite and chalcopyrite occur and a little of the orange-colored hydrocuprite is also found.

The copper is chiefly confined to the upper 30 inches of shale immediately under the extrusive trap sheet of First Mountain, and sometimes in the trap itself to a distance of about 6 inches from the contact. Locally it occurs at much greater distance from the contact, in both the trap and the shales. The dip is N. 50° E. 10 degrees. The metal is in minute grains, strings, sheets, and ragged masses of great variety of form and size. Many years ago a mass said to have weighed 128 pounds was found on the slopes near the mine; and a portion of it now in the Geological Museum of Rutgers College weighs 74 pounds, including perhaps a pound of attached and included shale. Occasional bits of native silver also occur. Immediately about the copper, even the smallest grains, the shale is bleached to a much lighter reddish brown, gray, or nearly white for a distance of one fourth to one or two inches. In these bleached portions, the thin lamination normal to the rock often disappears altogether.

The red shales of this region are often thickly interspersed with thin tabular crystals and clusters of calcite, ranging from very minute to more than an inch in diameter. They are apparently low, flat rhombohedra. Often in the surface portions of the shales, and usually in the mine, this calcite has been more or less removed by solution. In adjacent regions the cavities thus left are often lined with microscopic quartz crystals and sometimes divided by thin partitions of quartz, presumably deposited along cleavage planes of the calcite. In the mine, where the cavities are all small, slit-like openings, they are often partly occupied by little masses of copper and crystals of chalcocite; and this is usually true of both the bleached and unbleached portions of the shale. Near the trap, occasional crystals of prehnite and chalcopyrite also occur in these minute cavities.

Ores at Chimney Rock and Plainfield.—Identical conditions to those in the American mine, just described, led to prospect-

ing in the early days almost continuously throughout the four miles along First Mountain southeastward to Chimney Rock, where mines were opened, and again at Plainfield. Traces of these deposits are now discernible at the base of trap quarries at these localities, although the old workings are mostly inaccessible.

Ores Back of First Mountain.—The old Hoffman mine is three fourths of a mile southeast of Pluckamin and two miles northwest of the Somerville, or American mine. The ore, which occurs on top of the trap, is said to carry native copper. The old dump shows chalcocite in sandstone and brecciated trap, with smaller quantities of malachite. The breccia undoubtedly indicates faulting. A vertical fault of 4 to 6 feet throw was also encountered in the Somerville mine.

From this point around the inner or back slope of First Mountain for a distance of 17 miles copper minerals have been found at various places between the vesicular upper portions of the trap and the overlying sandstones and shales. Prospecting has been done near Martinsville, Warrenville, Washingtonville, and Feltville. At Feltville the ore was said to be sulphide, probably glance as at the Hoffman mine, associated with pyrite in thin seams between the trap and the shales.

The New Brunswick Mines.—About 1748 to 1750 many lumps of native copper from 5 to 30 pounds in weight, "upwards of 200 pounds in all," were plowed up in a field at New Brunswick in the area now partly included in the Neilson campus of Rutgers College. In subsequent workings sheets were found in the joints of the red shales and small grains disseminated through the rock. Similar sheets, one or two feet across, were also found in grading George street east of the College and in digging a cellar on Somerset street southwest of the campus. Cuprite, malachite, with a little chrysocolla and azurite sometimes incrust these sheets or entirely replace them. No trap is known to occur here, and wells in the immediate vicinity 455 and 480 feet deep, respectively, are entirely in the red shales.

The old Raritan mine is about 3 miles southwest of New

Brunswick. The rock in the old dumps is shale, and it is not known whether anything else was encountered in depth. Some small dikes cut the shales in the vicinity, however. Otherwise the conditions are apparently exactly the same as at New Brunswick.

Menlo Park Mine.—The old workings are half a mile north of Menlo Park, on the Pennsylvania railroad. The ore is native copper, in part altered to chrysocolla, in dark gray shale constituting the walls and breccia of a fault fissure. There are also minute grains of chalcopyrite and magnetite in the shale. The shales of the vicinity have the usual bright red color and dip 12 degrees north. At the mine they are traversed by a vertical north-south fissure along which the movement has been a nearly horizontal shove, or heave. The breccia, six inches to two feet in thickness, and about three feet of each wall are composed of the dark gray shale referred to above. On each side the color quickly changes, after a little mottling of gray and red, into the normal uniform red color of the region. Locally the gray is spotted and mottled slightly with nearly white bleached areas. No trap is known in the vicinity.

The copper occurs in thin sheets and films in joint-cracks and on the slickensided surfaces of the breccia and the walls. Minute grains and strings permeate the mass of the shale also, as well as the occasional bituminous plant remains that are found.

Copper at Glen Ridge.—The locality is four miles northwest of Newark, and traces of old workings are found just east of the public school building. Gray sandstone fragments are found with disseminated chalcocite and green with chrysocolla, as at the Arlington mine, and these minerals also penetrate and largely replace occasional bituminous plant remains. No trap is known within several miles of the locality.

Copper and Silver at Newtown.—Four miles northeast of New Brunswick, native silver occurs in scales and particles at Newtown, in gray sandstone stained green with chrysocolla. Specimens were collected at the surface but no work has been done.

Like New Brunswick, Menlo Park, and Glen Ridge, no trap occurs within several miles of the locality.

ORIGIN OF THE TRIASSIC COPPER ORES.

Whatever the economic aspects of these ores, they must continue to possess considerable scientific interest. Their simple structural relationships relieve them of the difficulties attendant upon the complicated conditions that prevail in many important mining districts; and conclusions drawn from their study should be correspondingly simple and clear, and should find profitable application in regions where the problems are more involved.

Kemp[1] has suggested that the copper has been derived from the chalcopyrite disseminated through the traps or from copper in the pyroxenes, but does not discuss the mode of accumulation.

Weed's Hypothesis.—In 1902 Weed[2] suggested a possible connection between the igneous activities and the deposition of the ores associated with intrusive traps at Rocky Hill and Arlington. Later, however, after an examination of the Rocky Hill mine, he ascribes the ores to the influence of percolating surface waters in the partial alteration of the trap.[3] This is the conclusion he had formerly arrived at in regard to the ores beneath the trap sheet of First Mountain, an extrusive mass. For the latter he gives the following probable sequence of events:[4] (*a*) Basalt chloritized, iron reduced from silicate to ferrous oxide: (*b*) calcite amygdules formed in basalt and pores of the altered shale; (*c*) copper dissolved out by percolating waters and carried downward; (*d*) copper and calcite deposited in pores of the ore; (*e*) glance reduced and ferric oxide reduced in white patches. For this last step he states that "the readiest agent at hand to reduce the glance to native copper is humic acid in waters containing oxygen," and "where organic matter, such as plant remains occurred the copper sulphide would

[1] "Ore Deposits of the United States," fifth edition, p. 223.
[2] Annual Report of the State Geologist of New Jersey for 1902, p. 131.
[3] Bulletin U. S. Geological Survey No. 225, 1904, p. 189.
[4] Annual Report of the State Geologist of New Jersey for 1902, pp. 136–139.

be reduced to native copper." He further supposes that the solutions carrying the copper "contained alkaline carbonates, and precipitated copper and glance with calcite."

Objections to Weed's Hypothesis.—Some of the difficulties involved in the foregoing hypothesis were fully appreciated by the author, who states, after summing up the conditions of occurrence: "It is hard to see how any single chemical sequence can account for facts apparently so contradictory, and it may be like Vogt's Norwegian cases, an example of reversed conditions." He also demonstrates how impossible it is to adapt the commonly accepted explanation of the Lake Superior deposits to the New Jersey ores. "It is evident that the commonly accepted explanation is not only not adequate, but contrary to the observed facts. If it were the protoxide of iron or of magnetite ferrous solutions that caused the reductions we should have red spots and ferric oxide, one of the most insoluble and stable of substances, associated with the native copper" instead of the bleached spots due to the reduction and leaching out of the ferric coloring matter of the red shales.

Some further difficulties in the application of Weed's hypothesis may be enumerated as follows:

1. The trap rock of First Mountain is not sufficiently altered to account for the underlying ores. On the basis of one fortieth of one per cent. original copper content, one fourth would have to be transferred without loss from a sheet 600 feet thick, in order to give an average of 2¼ per cent. in two feet of underlying shale, as actually reported in the Somerville mine. The great bulk of the trap is believed to be much less altered than this supposition requires, even with no allowance for loss of copper solution.

2. Ores are found above as well as below the First Mountain trap, and above the intrusive traps of Rocky Hill and Arlington. If these ores have been derived from the alteration of the underlying trap masses, an intricate system of meteoric circulation is required to account for their deposition above their source, and any such supposition is entirely inconsistent with the circulation required to deposit the ores below the trap.

3. The ore at Arlington, in addition to lying chiefly above the trap, is out of all proportion in quantity to the thin sheets of this rock with which it is associated. No determinations have been made of the copper content of the unaltered portions of this rock; but, unless this should prove to be exceptionally high, the ore-bodies would not only require all the copper from the trap sheets and dikes, but also a much larger additional supply from some unknown source.

4. An examination of the red shales south and southwest of the Somerville mine shows that they are often thickly interspersed with thin tabular crystals and clusters of calcite, ranging from almost invisible to more than an inch in diameter. This is, therefore, a normal constituent of the shales, and has not been supplied from the trap. The peculiar slit-like pores in shales of the Somerville mine are the result of leaching out of these crystals.

5. The calcite in amygdules and veins in the trap has unquestionably come from the alteration of the rock itself; but this is in no way associated in origin with the calcite that occurs so widely in the shales, far from the trap as well as near it.

6. Organic matter, if present in the shales, would undoubtedly aid in the reduction of the copper, as shown by occasional specimens found at Menlo Park and Glen Ridge; but the prevailing barrenness of the red shales in this respect is well known. Were it otherwise the almost universal red color of these rocks would constitute a problem no less difficult than the origin of the ores themselves. Practically no organic matter is found in the shale under First Mountain, and the amount found elsewhere is entirely inadequate to account for more than a minute fraction of the ore.

7. Weed's hypothesis fails to account in any manner for those ore-deposits that are in no way associated with trap rocks, as at New Brunswick, Menlo Park, Glen Ridge, and Newtown. At all of these localities the underlying Palisades intrusive must be some thousands of feet below and the extrusive sheet of First Mountain, if extended, would be at a considerably greater distance above. The only nearer trap masses are thin dikes and equally thin sheets connected with them.

A HYDROTHERMAL HYPOTHESIS.

The copper ores lie in a broad curved belt (see map, Pl. I) above the great Palisades-Rocky Hill intrusive sill and chiefly below the extrusive trap sheet of First Mountain. As pointed out in the preceding pages, they may be grouped into two classes, —those with intrusives and those without. Of the latter, some are under or over the lowest extrusive sheet and others are out in the midst of broad shale areas entirely apart from trap rocks of any kind. From the foregoing descriptions it is also clear that the ores of each of the leading types are remarkably uniform in character, the essential ore in the first (*i. e.,* with intrusives) being chalcocite, or glance, and in the second (*i. e.,* without accompanying intrusives) chiefly native copper.

Origin of Ores with Intrusive Traps.—The close association of these ores with intrusive sills, dikes, and apophyses indicates a genetic connection of some kind. That they were not derived merely by a later alteration of the trap is indicated both by the position of the deposits chiefly above the traps and by the great amount of ore as compared with the accompanying traps, particularly at the Arlington mine (Fig. 27).

There remains, therefore, the hypothesis of heated copper-bearing solutions, and possibly vapors, arising from the greater underlying mass of intrusives along the dikes and accompanying fissures, and depositing glance in the immediate vicinity while still highly heated. On account of pressure and the cooling effects of the surrounding strata, vapors could probably penetrate but a short distance from the igneous mass; and the chief effects may, therefore, be ascribed to solutions, probably to waters emanating directly from the magma.

The relatively impervious shales overlying the Rocky Hill intrusive served to greatly retard the escape of these waters to the surface. Dikes and accompanying fissures were confined to the immediate vicinity of the sill in this locality; and while the waters were thus impounded time was given for the accumulation of ores during the slow process of cooling. It is also quite possible that some reaction of the solutions with the calcite

of the shales contributed to the deposition of the copper-bearing mineral.

At Arlington the solutions followed the fissures of intrusion and their branchings in the adjacent sediments, and penetrated the breccias and porous sandstones, impregnating them with ore; and similar conditions may readily be conceived at Flemington.

Origin of Ores Apart from Intrusive Trap.—It has been demonstrated[1] experimentally in the laboratory of the U. S. Geological Survey that a solution saturated with cuprous sulphate will deposit metallic copper on cooling; and therefore a solution in which cupric sulphate has been partly reduced to cuprous sulphate by ferrous sulphate, pyrite, chalcocite, siderite, or silicates rich in ferrous iron, will deposit metallic copper if carried to a cooler region. Hence those Triassic ores of New Jersey not associated with intrusive trap are readily conceived to be deposits from heated waters, probably emanating from some underlying intrusive magma, either a subterranean portion of one of the extrusive sheets, or more probably the great Palisades-Rocky Hill sill and its various branchings and ramifications through the sediments. Such waters must have permeated this area extensively at the time of this great intrusion and during the long period of cooling that followed, especially along the fissures and joints of the overlying shales and sandstones and the extrusive trap sheets.

The movements of these solutions through the sediments were sufficiently retarded under certain conditions to permit the accumulation of considerable deposits through progressive cooling. Perhaps these were augmented also by reactions with the disseminated tabular calcite of the shales, thus removing the calcite and leaving the slit-like cavities more or less occupied by copper and copper-bearing minerals. The acid sulphate solutions also leached out the ferric coloring matter of the red shales, leaving the bleached areas to mark the impregnated portions of the rock. Those waters that escaped through the more extensive fissures were in part intercepted by the trap sheet of First Mountain;

[1] H. N. Stokes, Economic Geology, Vol. I., 1906, pp. 644-650.

other portions finding passage through the joints and fissures of the trap formed lesser deposits under the overlying shales, and to a certain extent in the midst of the trap itself.

At New Brunswick the underlying Palisades trap is as near as at the Arlington mine, and dikes that penetrate the shales to within a short distance of the city to the east, south, and southwest, give evidence of the extent to which the strata in this vicinity were fissured. At Menlo Park the ores are confined to a well-defined fissure through which the solutions have come. The copper-bearing minerals of Newtown and Glen Ridge, together with the native silver at the former locality, as under First Mountain, were doubtless formed under exactly similar conditions.

Summary of Origin.—In all cases the Triassic copper ores of New Jersey are attributable to the same source; namely, hot copper-bearing solutions, probably of magmatic origin, deriving both their heat and their copper salts from the great underlying Palisades trap sill and its offshoots. The deposition of chalcocite by the heated waters near the intrusive, and of native copper with minor amounts of glance in the more remote, cooler regions, has in both cases doubtless been chiefly the result of cooling, supplemented perhaps in part by reactions with the calcite of the shales. The conditions of considerable accumulation have been supplied by some relatively impervious member, a dense shale or a trap sheet, which has sufficiently impeded the movements of the uprising solutions to permit considerable cooling, and, therefore, extensive deposits, and also to allow time for any possible reactions with the calcite and for leaching out the ferric iron, in part, by the acid waters.

MAGMATIC EMANATIONS.

FRANCIS CHURCH LINCOLN.

INTRODUCTION.

A knowledge of the nature of the emanations from cooling igneous magmas is of great importance to the economic geologist. These emanations have been most frequently discussed in connection with theories of vulcanism or of the pneumatolytic deposition of ores, hence an article treating of them directly may prove of value. It will at all events place in the hands of those engaged in the investigation of ore deposits a condensed statement of the facts thus far established.

This paper was undertaken at the suggestion of Professor J. F. Kemp, to whom the writer desires to express his thanks for advice during its preparation.

CLASSIFICATION.

When our knowledge of magmatic emanations shall have become wider, it will doubtless be found advisable to classify them according to origin, but at present such a classification is impracticable, if not actually impossible. For the purposes of the present paper, a classification of emissions made along the line of our sources of information respecting them will be most satisfactory. In 1903, Weed[1] stated that our knowledge of magmatic emanations had been derived from "(1) analyses of the gaseous emanations of volcanoes and lava-flows; (2) analyses of the gases occluded in cold rocks; (3) analyses of the sublimation products formed by fumaroles; and (4) evidence of contact metamorphism of included masses of sediments entirely surrounded by the igneous rock." Other sources of information are now available, which, taken in conjunction with those noted by Weed, suggest the following classification of magmatic emanations:

[1] *Trans. A. I. M. E.*, 33, 739.

I. Actual Emanations.
   1. From lava-flows.
   2. From volcanoes.
   3. From deep-seated magmas.

II. Fossil Emanations.
   1. Inclusions in minerals.
   2. Minerals in druses and lithophyses.
   3. Minerals at igneous contacts.
   4. Minerals in veins.

III. Repressed Emanations.
   1. Of volcanic rocks.
   2. Of plutonic rocks.

IV. Potential Emanations.
   1. Of igneous rocks.
   2. Of sedimentary rocks.

Actual emanations are those actually in process of emission from cooling igneous magmas. Fossil emanations are remains or traces of past actual emanations which have been preserved in some manner. Repressed emanations are those which would have been generated by igneous rocks at the time of their formation had the pressure upon them not exceeded that of the atmosphere and had they remained at a high temperature for a sufficient length of time. Potential emanations are those which rocks are capable of producing if heated to a high temperature under atmospheric pressure. In the case of igneous rocks potential emanations necessarily include repressed emanations.

ACTUAL EMANATIONS.

Actual emanations may be observed rising as gases and vapors from lava-streams, expelled from volcanic vents, and issuing forth as springs generated by deep-seated magmas. Upon recent lava-flows and at active vents, the emissions are susceptible of direct observation at or shortly after the time of their expulsion, but plutonic emanations cannot be seen until long after they have left their source.

Notwithstanding the accessibility of volcanic craters there are obvious difficulties in the way of obtaining samples of the gases concerned in great volcanic eruptions. Under favorable conditions, the gases given forth during the less violent out-

breaks of volcanoes may be determined qualitatively by means of the spectroscope. It is occasionally possible during quiet eruptions to take samples directly above the volcanic vent (*e. g.*, Table I, Emanation 19), but quantitative determinations of emissions from volcanoes in eruption are usually made upon samples from side-wall crevices, lava fumaroles or submarine vents, while analyses of gases from the eruptive center are of samples obtained during periods of quiescence.

Janssen[1] studied the volcanic flames of Santorin spectroscopically in 1867 and found the chief combustible gas to be hydrogen. Sodium was always noted and the presence of copper, chlorine and carbon was also indicated. At Stromboli the flames were found to be of similar composition. In 1883 Janssen[2] had an opportunity to examine the flames of Kilauea with a spectroscope. He found in them sodium, hydrogen and hydrocarbons. Libbey[3] investigated the Kilauean flames independently in 1893. With a pocket spectroscope he was able to detect carbon dioxide and hydrocarbons.

Volcanic emanations are collected in the form of gases and vapors, but upon cooling the sample may be found to include gases, liquids and solids. The principal liquid is water. This is usually noted as "a little," "much," or "an enormous quantity," but since this water is an essential part of the emanation (except in the case of submerged vents), its quantitative relations with the gas should be stated, as has been done in Emanations 12 and 29 of Table I. It is also customary not to subject this water to a quantitative determination, but simply to test it qualitatively. It would be better, whenever possible, to make a quantitative analysis, figuring gaseous constituents in solution, like HCl, back into the gas analysis, stating the proportions of any liquids present, and figuring dissolved solids in with sublimates. Sublimates and dissolved solids are usually present in such minute amounts proportionally to the gases and water, that the quantity of emanation taken for the sample is

[1] *Comptes Rendus*, **64** (1867), 1303.
[2] *Comptes Rendus*, **97** (1883), 371.
[3] *Amer. Jour. of Sci.*, [3], **47** (1894), 371.

not sufficient for a satisfactory determination. Fortunately, however, these solids frequently collect about the mouths of fumaroles, and thus coatings which have taken hours or days to form may be obtained and analyzed. The analyses of sublimations as given in Table I have been made upon this class of material.

Out of a collection of over two hundred distinct volcanic emanations, fifty have been selected and placed in Table I. These fifty were selected (1) to show geographic range and (2) to show variety of chemical composition. The average of these fifty emanations does not represent a typical volcanic gas, but is simply of value for purposes of comparison and as roughly indicating the nature of the composite volcanic gas poured into the earth's atmosphere.

From this average, it would appear that nitrogen, with an average percentage of 44.361 in the cases cited, is the most important volcanic gas. The question arises, however, as to how much of this nitrogen has actually come from the lava and how much has been derived from air which has become mixed with the true volcanic emanations after their ejection from the lava and before their collection in the sample. The same question may be asked with regard to the oxygen which makes up 9.026 per cent. of the average. A considerable proportion of this nitrogen and oxygen may be due to contamination by air, but it seems almost certain that some of each gas is original. For in the case of submerged vents like those which gave Emanations 2, 18, 41 and 42, one seems forced to the conclusion that both oxygen and nitrogen are original; although in cases where sea-water is concerned, as in Emanations 17, 46 and 47, one is at liberty to question whether these gases may not, at least in part, have been driven from solution in circulating sea-water by the heat. In Emanation 3, from a high pressure fumarole, it would also appear that part at least of the oxygen and nitrogen must be original. Additional evidence of a confirmatory nature is offered by Emanations 2, 3 and 18 when their content of argon is considered; for the ratio of argon to nitrogen is higher than

Table I. Volcanic Emanations.

No.	Volcano (or Locality).	Conditions.	Temperature. °C.	Composition of Gas in Parts per Hundred. CO_2	CO	C_2H_4	CH_4	H_2	HCl	H_2S	SO_2	O_2	N_2	A	He	Accompanying Substances. Water.	Sublimates.
1	Pelée.	Low pressure fumarole.	400	15.38	1.60	0	5.46	8 12	—	0	—	13.67	54.94	0.71	—	Water. NH_4Cl, S, tr. $(NH_4)_2SO_4$?	As sulphide.
2	Soufrière.	Inundated "	96	52.8	0	0	0	0	Tr.	2.7	—	7.5	36.07	0.73	—	Water with Ca and Fe salts.	S
3	"	High pressure "	95–96	69.5	0	0	0	0	0	4.5	—	2.7	22.32	0.68	—	Water with Ca salts and Fe_2O_3.	S
4	Tolima.	Fumarole.	50	14	—	—	—	—	0	Tr	—	17.2	68.8	—	—*a*	"	—
5	Purace.	"	86.5	85	—	—	—	—	0	—	—	3.15	11.85	—	—	"	S
6	Pasto.	"	(Melted Bi, not Pb) 78	—	—	—	—	—	0	Tr.	—	4 4	17 6	—	—*a*	"	Alum and $CaSO_4$.
7	(Tuquerres).	"	86	99.5	—	—	—	—	0	0.5	—	—	—	—	—	"	S
8	Cumbal.	"	<85	99.9	—	—	—	—	0	0 1	—	—	—	—	—	"	—
9	Hekla.	"	—	2.44	0	—	0	—	0	0	1.54	14.21	81.81	—	—	} Water with tr. HCl. NaCl 5 65%, $CaSO_4$ 63.41%, $MgSO_4$ 12 68%, Na_2SO_4 16 78% and K_2SO_4 0.88%.	
10	"	"	—	0.56	0	—	0	—	0	0	—	16.86	82 58	—	—		
11	"	Lava fumarole.	—	1 01	0	—	0	—	0	0	—	20.09	78.90	—	—	Water with tr. HCl and H_2SO_3. NH_4Cl and other chlorides (*b*).	
12	(Iceland).	Fumarole.	—	87.43	0	—	0	—	—	6.60	—	—	1.67	—	—	82.30% of gas was steam.	S
13	"	"	—	50 00	0	—	0	—	—	24.12	—	—	0.72	—	—	Water	—
14	"	Great Geyser.	—	8.92	0	—	0	—	—	0 38	—	—	84 11	—	—	"	—
15	(St. Paul Is).	Fumarole.	92	94.71	—	—	—	—	—	—	—	—	5 29	—	—	"	—
16	"	"	78–80	14.52	—	—	—	—	—	—	—	16 67	68.81	—	—*c*	"	—
17	(Terceira Is.).	Thro' 205 fathoms sea-water.	—	2 27	—	—	16.75	0.32	—	—	—	12 21	68 45	—	—	—	—
18	(Larderello).	Suffioni.	—	92 400	0	—	1.650	2 500	—	2 035	—	0.125	1.252	0 025	0 012*c*	Water with tr. H_3BO_3.	
19	Vesuvius.	Directly above vent.	(Melted Ag)	—	—	—	—	—	Tr.	—	—	9	91	—	—	Water with $FeCl_3$. NaCl(tr. $CoCl_2$), $FeCl_3$, K salts, tr. CuO.	
20	"	Lava fumarole.	(Melted Zn)	10 50	—	—	—	—	—	0	—	17 24	72.26	—	—*d*	Water.	NaCl and NH_4Cl.
21	"	" "	Tr.	—	—	—	—	—	—	—	—	13 76	86.24	—	—	A little water. NaCl 96.566%, KCl 1.281%, Cu_2Cl_2 2.157% (*g*).	
22	"	" "	305–400 ±	—	—	—	—	—	—	—	0.19	20.49	79.32	—	—*e*	No water.	NaCl with a little of other salts (*h*).
23	"	Fumarole.	—	2.80	—	—	—	—	2 37	—	2.06	19.17	73.60	—	—*d*	—	—
24	"	"	66–154	0	—	—	—	—	—	—	1 60	19.08	79 32	—	—*f*	Enormous quantity water with HCl and H_2SO_4.	—
25	"	"	218	5.38	—	—	—	—	—	—	Tr.	18 46	76 16	—	—	—	—
26	"	"	89	7-43	—	—	0	0	—	0	—	18.62	73.95	—	—*d*	Enormous quantity of water.	—
27	"	"	—	90.2	—	—	2.8	—	—	—	—	0 8	6 2	—	—	—	—
28	"	"	—	85.38	—	0 05	0.95	0	—	Tr	—	2 85	9 38	—	—	—	—
29	La Solfatara	High pressure fumarole.	112	99.1	—	—	—	—	—	0 9	—	—	—	—	—	About 95% of gas was steam.	—
30	"	Fumarole.	72–92	20.0	—	—	—	—	—	9 1	—	14.2	56.7	—	—*c*	Enormous quantity of water.	S
31	"	"	87	8.02	—	—	—	—	—	—	—	18 71	73.27	—	—	—	—
32	Etna.	"	99	—	—	—	—	—	—	—	0.4	20 5	79.1	—	—	Water with HCl and H_2SO_3.	$FeCl_3$.
33	"	"	—	5.00	—	—	—	—	—	0 45	—	17.27	77.28	—	—	—	S
34	"	"	41–82.5	10.6	—	—	—	—	—	—	—	15.2	74.2	—	—	Emanations essentially water	—
35	"	Mud volcano.	46	92.53	—	—	1.49	0.99	—	0 30	—	0 12	4.70	—	—	Water with many salts in solution (*i*).	
36	"	" "	—	95-35	—	—	1.12	0 50	—	—	—	0 58	2.94	—	—	Saline water.	$CaSO_4$.
37	Vulcano.	Fumarole.	360	23.40	—	—	—	—	73 80	—	Tr.	0.52	2.28	—	—	—	$FeCl_3$, As sulphides, NH_4Cl. (NoS or H_3BO_3.)
38	"	Flaming fumarole.	(Melted Pb, not Ag)	0	—	—	—	—	—	—	24.40	14 54	61.06	—	—*c*	—	(No H_3BO_3.)
39	"	Fumarole.	60–120	—	—	—	—	—	—	—	6 1	16 9	77.0	—	—*c*	—	S, NH_4Cl (tr I) As sulphides (Se and tr. P), H_3BO_3.
40	"	"	100	68 8	—	—	—	—	7.3	10.7	—	2.7	11.2	—	—	—	S, with or without H_3BO_3.
41	"	Water-filled depression.	82	8.1	—	—	—	—	—	83.0	—	0 6	8.3	—	—*c*	—	—
42	"	" "	25	86.0	—	—	—	—	—	—	—	0.1	13 9	—	—*d*	—	—
43	Santorin.	Fumarole.	115	68.5	—	—	—	—	19.4	—	12 0	—	—	—	—	—	—
44	"	"	122	12.24	—	—	—	—	—	0.90	—	16 41	70 45	—	—	—	S
45	"	"	160	17 28	—	—	0.49	Tr.	—	1.64	—	14 12	66 47	—	—	Considerable water with HCl and less H_2SO_3.	S
46	"	Sea-water milky with S.	61	35 60	—	—	0 81	30 09	—	Tr	—	1 46	32.04	—	—	—	—
47	"	Sea-water.	—	—	—	—	—	—	—	—	—	10	90	—	—	—	—
48	(Nisyros).	Fumarole.	—	38.4	—	—	0 4	1.5	—	57.1	—	—	2 4	—	—	Water	—
49	"	"	100	49.2	—	—	—	—	—	44.5	—	1 0	5.2	—	—	"	Abundant S
50	"	"	70	7.0	—	—	—	—	—	0	—	18.1	74.8	—	—	"	—
	Average.			36.303	0.032	0.001	0.638	1.601	2.057	4.991	0.966	9.026	44.360				

NOTES.—*a* "Air" computed to O_2 and N_2. *b* NH_4Cl 78.00%, $FeCl_3$ 5.90%, $AlCl_3$ 2.00%, $MgCl_2$ 3.57%, $CaCl_2$ 2 58%, NaCl 2 03%, KCl 0 62%, SiO_2 0.60%, Water and foreign 4 20%; being the average of two analyses. *c* Average of analyses of two gases. *d* Of three gases. *e* Of four. *f* Of five. *g* Average of analyses of three different sublimates. *h* NaCl 94 3%; $MgCl_2$ (tr. Fe) 0 6%, Na_2SO_4 0.2%, K_2SO_4 1.0%, $MgSO_4$ 0.4%, $CaSO_4$ 0.2%, Hyg. H_2O 0.8%. *i* Bases: Na, K, Ca, Mg, Al, Fe, tr. Li, tr. Cs, tr. Rb; acids: H_2CO_3, $H_3(PO_4)_2$, HNO_3, HCl, HBr, HI, HF.

| | | |

39. Ste.-Claire Deville: *l. c.*, 683.
40. Fouqué: *l. c.*
41. Ste.-Claire Deville: *l. c.*, 685. Ste.-Claire Deville and Leblanc: *l. c.*, 46–7.
42. Ste.-Claire Deville: *l. c.* Ste.-Claire Deville and Leblanc: *l. c.*, 47–8.
43. Gorceix: *l. c.*, 270.
44. Fouqué: *C. R.*, **64** (1867), 186–7.
45. *Ibid.*
46. *Ibid.*
47. *Ibid.*, 667.
48. Gorceix: *C. R.*, **78** (1873), 1309.
49. *Ibid.*, 445.
50. *Ibid.*

in air. Moreover in Emanation 18 the ratio of helium to argon and nitrogen is enormously greater than it is in air. Special arguments may be advanced for the originality of the nitrogen. The proportion of nitrogen to oxygen is usually greater than in air and at times nitrogen is present entirely unaccompanied by oxygen. While a small amount of oxygen might readily be removed by secondary reactions after the emanations had been set free from the lava, such an explanation would hardly account for the more pronounced instances of low or lacking oxygen content. As we shall see later, nitrogen has been found in both fossil and repressed emanations, though the presence of oxygen in either case has not as yet been noted. It seems probable that, could the proper deductions be made for introduced air, nitrogen would be reduced to at least second place and oxygen would either be entirely lacking or present as one of the minor constituents only.

Conceding this to be the case, one may look upon carbon dioxide as the most important volcanic gas. A small amount of this gas may come from introduced air, but as it is present in air to the extent of only 0.03 per cent., the amount so introduced is almost negligible. Carbon monoxide has been found in one instance,—Emanation 1,—accompanying the carbon dioxide. Next in importance come the sulphurous gases, with hydrogen sulphide making up 4.991 per cent. of the average and sulphur dioxide, which may all have been derived from hydrogen sulphide by combustion, making only 0.966 per cent. Then, in order come hydrochloric acid, hydrogen and methane, with a trace of ethane.

Of the non-gaseous constituents of volcanic emanations, water heads the list, while the more important solids are sulphur, salt, sal ammoniac, gypsum and ferric chloride. The nature of the solids present in lesser quantities has been studied most thoroughly in the Æolian Isles and at Vesuvius. Abich[1] found that at Stromboli hydrochloric acid was the principal acid of the sublimations with lesser quantities of sulphuric acid. The bases were ammonium, iron, calcium, aluminum, and magnesium, with traces of sodium, potassium, copper, nickel and tin. Native sulphur was also present. At Vulcano[2] there have been found: sulphur, tellurium, realgar, boric acid, salt, sal ammoniac, ferric chloride, glauberite, lithium sulphate, glauber salt, alum with thalium, rubidium and cæsium, hieratite ($2KFl \cdot SiFl_4$), cobalt, zinc, tin, bismuth, lead, copper, iodine and phosphorus. In the Vesuvian eruption of 1895, Matteucci[3] noted among the products of the fumaroles: hydrochloric acid, sulphurous anhydride, hydrogen sulphide, carbon dioxide, sulphur, calcium sulphate, various sulphates and chlorides of iron and of copper, erythrosiderite, chlorides and sulphates of sodium and of potassium, sal ammoniac, tenorite, and hematite, together with selenium, hydrofluoric acid, hydriodic acid, hydrobromic acid, and sodium bicarbonate. In the eruption of 1900 iron nitrate was produced at the same time as sal ammoniac.[4] In the last eruption of Vesuvius the fumaroles produced, according to Lacroix:[5] chlorides of iron, sodium, calcium, magnesium, etc., including erythrosiderite; realgar, sulphur, galena, magnetite, hematite, pyrrhotite, pyrite, and cotunnite; tenorite, chlorides and sulphates of potassium, sodium and copper, with a little calcium and magnesium. Thus the minor constituents of volcanic emanations have been shown to include all the economic metals with the exception of gold and silver.[6]

[1] *Zeit. deutsch. geol. Ges.*, 9 (1857), 403.
[2] Bergeat, *Abh. Munich Akad. Wiss., math.-phys. classe*, 20 (1900), 193.
[3] *C. R.*, 129 (1899), 65–6.
[4] Matteucci, *C. R.*, 131 (1900), 963–5.
[5] *C. R.*, 143 (1906), 727–730.
[6] The galena in the ejected marble blocks of Monte Somma is argentiferous, as noted by Matteucci, *Centralblatt f. Min. Geol. u. Pal.* (1900), 47, so that of the Vesuvian fumaroles may contain silver.

Actual plutonic emanations cannot, of course, be observed at the time of their emission. Many mineral springs may be of magmatic origin, but since their starting points are inaccessible they can be proved to be juvenile only by showing that they cannot be meteoric. Thus it has been argued that the Karlsbad Springs must originate from a cooling magma because they are situated in the midst of a large granite area and the quantities of water, carbon dioxide, and sodium salts which they contain cannot be explained by the infiltration of surface waters and leaching of the granite.[1] These springs are therefore probably actual plutonic emanations. The Karlsbad Springs hold in solution salts containing the elements chlorine, fluorine, boron, phosphorus, sulphur, selenium, thalium, rubidium, cæsium, arsenic, antimony, zinc, sodium, potassium, lithium, calcium, magnesium, strontium, barium, iron, manganese, aluminum, and silicon.

FOSSIL EMANATIONS.

Fossil emanations are the more or less well preserved remains and traces of actual emanations. The complete preservation of past emissions is often seen in inclusions in minerals, while partial preservation is common in druses and lithophyses, at contacts and in veins.

Gases, liquids and solids enclosed in impermeable original cavities in the crystals of igneous rocks constitute samples of emanations from the magma at the time those crystals were formed. Sorby[2] found that the fluid in the cavities of the quartz of elvans and granites which he examined was water holding in solution chlorides of sodium and potassium and sulphates of sodium, potassium and calcium. Sometimes one salt, sometimes another, was in excess; occasionally there was more salt than the water could hold in solution; and often there was an excess of acid. Vogelsang and Geissler[3] found water and carbon dioxide in the cavities of the quartz of a granite from

[1] Suess, *E. and M. J.*, **76** (1903), 52.
[2] *Jour. Geol. Soc.*, **14** (1858), 487.
[3] *Pogg. Annal.*, **137** (1869), 56.

Saxony. Pfaff[1] conducted an interesting series of quantitative experiments in this line. He prepared samples by heating them to a low red heat and cooling in a desiccator. He then determined the water by grinding the specimens very fine in a current of dry air and weighing the moisture gathered up by this air. He concluded that granites, gneisses, etc., and the crystals of quartz and feldspar from granites, etc., all contain mechanically enclosed water and sodium chloride. The minimum quantity of water was found in a syenite from Meissen which contained 0.11 per cent. and the maximum in a mica schist from Davos with 1.8 per cent. Lava, obsidian and basalt were found to contain no mechanically enclosed water. Wright[2] analyzed the inclusions so plentiful in the pegmatitic quartz of Branchville, Conn. The gas from these cavities was 1.31 times the volume of the quartz and the water was 0.163 per cent. of the weight of the quartz. The gas consisted of 98.33 per cent. carbon dioxide and 1.67 per cent. nitrogen with traces of hydrogen sulphide, sulphurous anhydride, ammonia, fluorine and possibly chlorine. In addition to the gas and water, there were present in the cavities sodium chloride and a hydrocarbon of the nature of bitumen.

In druses in the nevadite of Chalk Mountain, Colorado, Cross[3] found sanidine, quartz, biotite, a few ore grains, and occasionally a topaz crystal. The appearance of these associated minerals suggested to him that they might be all sublimation products. Upon examining the minerals of lithophyses in rhyolite from Nathrop, Colorado, Cross[4] found a similar series of minerals. But in addition to the minerals found at Chalk Mountain, spessartite was discovered and some of the ore grains were believed to be hematite. Cross decided these minerals were "primary, and produced by sublimation from presumably heated solutions, contemporaneous, or nearly so, with the final consolidation of

[1] *Ibid.*, 143 (1872), 610.
[2] *Amer. Jour. of Sci.*, [3], 21 (1881), 209.
[3] *Ibid.*, 27 (1884), 94.
[4] *Ibid.*, 31 (1886), 432.

the rocks." Iddings[1] has identified quartz, tridymite and fayalite in lithophyses of obsidian and rhyolite from the Yellowstone National Park. Roth[2] mentions augite as occurring in druses.

The other varieties of fossil emanations, minerals at some igneous contacts and in some veins, have been so often and ably described in works upon ore-deposits that it seems unnecessary to discuss them at length in the present paper. It is well to remember in this connection that while the minerals of veins and contacts frequently appear to be in whole or in part of magmatic origin, in any individual instance it is almost as difficult to prove this to be the case as it is to prove that a certain hot spring is juvenile. For heat from an intruded magma will set free as secondary emissions part of the potential emanations of the rock into which it is forced, will start new circulations of meteoric waters and will stimulate old ones and thus effects may be produced similar to those which magmatic emanations would bring about. Thus in order to prove that the emissions from cooling magmas have contributed in an important way to the composition of contact zones and mineral veins, it is not only necesary to show that they might have done so but also that no other agent could have.

Ore deposits probably of pneumatolytic origin contain all the metals and mineralizers which have been found in actual emanations together with a few which up to the present time have not been so found.

REPRESSED EMANATIONS.

When unaltered igneous rocks are heated to a high temperature: (1) absorbed gases and gasifiable substances may be driven off, (2) the gases and gasifiable substances in cavities may be set free and (3) some of the solids present may decompose or react upon one another to form new gases. These latter gases, the gases of composition, may be designated as repressed emanations because had the igneous rock containing them remained at a suffi-

[1] *Ibid.*, 30 (1885), 58.

[2] "Allgemeine u. Chemische Geologie" (1885), Vol. 2, p. 215.

TABLE II. REPRESSED GASES OF IGNEOUS ROCKS.

Rock.	Locality.	Authority.	Volumes Gas per Vol. Rock.	Percentage Composition of Gas.						Water	
				CO_2	CO	CH_4	H_2	H_2S	N_2	Parts by Weight per 1000.	Lost During Preliminary Heating.
1. Granite	Skye.	Tilden.	2.2 (*c*)	23.60	6.45	3.02	61.68	—	5.13	—	—
2. Gabbro	Lizzard.	Tilden.	6.4 (*b*)	5.50	2.16	2.03	88.42	—	1.90	—	—
3. Basalt	Antrim	Tilden.	8.0 (*b*)	32.08	20.08	10.00	36.15	—	1.61	—	—
4. Basalt	Skye.	Travers.	.49	0	0	—	100.00	—	—	—	—
5. Granite	Vire.	Gautier (*a*).	8.4	12.73	5.18	1.77	78.79	0.80	0.55 (*d*)	7.35	2.29
6. Quartz Diorite Porphyry	Esterel.	Gautier.	7.4	59.25	4.20	2.53	31.09	0	2.10	12.40	5.80
7. Ophite	Villefranque.	Gautier (*a*).	7.6	31.49	4.40	1.35	59.49	3.15	0.29	15.06	—
8. Lherzolite	Lherz.	Gautier.	15.7	78.35	1.99	.01	7.34	11.85	Tr.	16.80	—
Average			7.024	30.375	5.558	2.589	57.870	1.975	1.448	12.903 (*e*)	4.045 (*f*)

NOTES.—*a*. Average of three analyses; *b*. From another sample of same rock; *c*. Average of analyses of two other samples; *d*. Rich in argon; *e*. Average of last four analyses only; *f*. Average of analyses of gases 5 and 6 only.

CITATIONS.—Tilden, *Proc. Roy. Soc.*, **60** (1897), 455; Travers, *Ibid.*, **64** (1899), 130; Gautier, *Comptes Rendus*, **132** (1901), 58.

ciently high temperature and low pressure for a sufficient length of time they would have been generated as magmatic emanations. The nature and quality of repressed emanations are evidently dependent upon the composition of the rock, the temperature and the pressure.

According to Brun,[1] nearly all lavas emit gases when remelted, often in such quantities as to cause veritable explosions. The gases so generated are: Nitrogen and ammonia, chlorine and hydrochloric acid, hydrocarbons and substances derived from them by decomposition and combustion. Only insignificant quantities of steam are formed.

The repressed emanations of some igneous rocks have been investigated quantitatively and the results appear in Table II. A glance at this table shows water to be the principal substance generated in igneous rocks by the action of heat. Then, in order, follow hydrogen, carbon dioxide, carbon monoxide, methane, hydrogen sulphide and nitrogen. The main points of difference between these gases and volcanic gases are such as can be explained by the introduction of air into the gases generated by the volcanic magma. In this way the amount of hydrogen in a generated gas would be reduced by the formation of water, the amount of carbon dioxide would be increased and of carbon monoxide decreased by the oxidation of the latter, and sulphur dioxide and water would be formed by the combustion of hydrogen sulphide while at the same time the quantity of nitrogen would be increased and oxygen, if not entirely consumed, would be added to the list of gases.

POTENTIAL EMANATIONS.

Potential emanations exist in all rocks. They are the gases which would be evolved by a rock if it were heated to a high temperature under atmospheric pressure. Looked at in another way, they are the largest quantity of secondary emanations which can be produced from a rock as a result of the intrusion of a magma. From still another point of view, they are the

[1] "Quelques recherches sur le volcanisme," *Arch. Sci. phys. et nat.* [4], **19**, 439–450 and 589–606.

greatest amount of gases which a rock could evolve if it were in any way converted into a magma. Were a magma derived from a rock by fusion, the potential emanations of the rock would be separated into two portions, one being expelled as actual emanations and the other being retained as repressed emanations.

The potential emanations of an igneous rock are present as repressed emanations, absorbed substances, and fossil emanations. Repressed emanations and fossil emanations have already been discussed. The principal absorbed substance is water which is present in extremely variable amount. In Table II the amount of absorbed water in connection with gases 5 and 6 is given.

The potential emanations of sedimentary rocks are of somewhat similar nature to those of igneous rocks. They are present as substances in chemical combination, substances in cavities and absorbed substances. No data as to their chemical composition are available, but it is evident that a pure sandstone would give rise to but little gas, a limestone to immense quantities of carbon dioxide, and that in general much more steam would be generated than from igneous rocks.

Potential emanations are the source of the secondary magmatic emanations induced in rocks by the heat from intruded magmas. The relative amounts of primary and secondary emanations evolved in any particular case are not known, and the ratio probably varies widely. Investigation is greatly complicated because magmas may absorb by contact substances of the nature of potential emanations and give them forth later as direct magmatic emanations.

SOURCE OF THE EMANATIONS.

Travers[1] has said: "In the *majority of cases* where a mineral substance evolves gas under the influence of heat, the gas is the product of the decomposition or the interaction of its *non-gaseous* constituents at the moment of the experiment." There seems to be little doubt that the emanations derived from dry

[1] *Proc. Roy. Soc.*, **64** (1899), 142.

unaltered igneous rocks are due to the decomposition or interaction of minerals which compose the rock. The following explanation of the observed facts seems reasonable. In order that certain rock minerals shall produce emanations two conditions must be fulfilled: the heat must be high and the pressure must be low. Lavas retain potential emanations because they have cooled so rapidly that they have not had time to generate them while plutonic magmas retain them because they are under such great pressures.

Brun[1] believes the generators in the case of the Mediterranean volcanoes to be: For nitrogen, nitride of iron and nitride of silicon,—"Marignacite,"—for chlorine, the combined silicate and chloride of calcium; for hydrogen and carbon, heavy hydrocarbons; and for oxygen, polybasic ferric silicates. Reactions between these generated substances give rise to the gases observed. Brun's theory is founded upon both analytic and synthetic investigations.

Gautier[2] conducted analytic and synthetic work which led him to somewhat different conclusions as to the nature of the generators. Water set free at a high temperature reacts upon ferrous silicates and analogous compounds to form ferrous-ferric and ferric compounds and free hydrogen. Water reacting upon siderite at temperatures even below red heat sets free carbon monoxide, carbon dioxide and hydrogen. Hydrogen sulphide is formed (*a*) by the decomposition of iron and manganese sulphides by water; (*b*) by the reduction of sulphates by nascent hydrogen to sulphides and their destruction as in (*a*), and (*c*) by the decomposition of sulphosilicates by water. Nitrogen, ammonia, argon and helium result from the decomposition of nitrides, argonides and helides. Traces of nitrides and cyanides are present and are decomposed by water at red heat forming nitrogen and ammonia. Methane and traces of petroleum are formed from metallic carbides decomposed by water at high temperatures.

[1] *Op. cit.*

[2] *Bull. Soc. Prim.* [3], 29 (1903), 191. In more recent work (Ec. Geol., 1, 688), Gautier has complicated his results by introducing exhalations from a supposed incandescent metallic nucleus of the earth.

Thus Gautier attributes the formation of the repressed emanations mainly to the action of water while Brun explains the formation of the same gases without water. Each was doubtless correct within the range of his own experiments, for considerable difference must exist between the generators left in the intrusive rocks and those left in the extrusive rocks, since the repressed emanations are retained under such different conditions in the two cases. It should be borne in mind, however, that while Gautier was dealing with solid rocks Brun was dealing with melted lavas. Brun's analyses were upon solid generators and lavas, his experiments upon melted ones. When these solids melted and dissolved in one another, the nature of the generators may have been somewhat different, ions rather than compounds becoming of importance.

It is apparent that primary magmatic emanations are of similar origin to repressed emanations, if the view advanced here that repressed emanations are simply actual emanations kept back by cooling or pressure or both cooling and pressure is true. Thus the magma may best be looked upon as an extremely complicated system of liquids and gases. Any relief of pressure leads to a rearrangement of this system whereby emanations are given forth and a part of the generators are destroyed in giving birth to more of the gas. Increased pressure causes the absorption of gas and the formation of more of the generators. Cooling of the magma will cause it to solidify, but the formation of emanations may continue till a temperature slightly below red heat is reached, providing the pressure is low.

CONCLUSIONS.

Magmas contain certain substances which decompose or interact unless prevented by pressure or cooling. These generators give rise to primary magmatic emanations. Cooling or pressure or both cooling and pressure prevent the complete destruction of the generators, hence igneous rocks contain repressed emanations which may be expelled by heating them to red heat at atmospheric pressure.

Intruded magmas by heating the adjoining rocks induce sec-

ondary emanations which consist of part of the potential emanations of these rocks. The ratio of primary to secondary emanations is an unknown quantity.

Magmatic emanations which are expelled as gases and vapors become at the ordinary temperatures of the earth's surface solids, liquids and gases. The principal gases are carbon dioxide, methane, hydrogen, hydrochloric acid, hydrogen sulphide, sulphur dioxide, nitrogen and oxygen, with less carbon monoxide and ethane and a very little hydrofluoric, hydriodic and hydrobromic acids. Water is the only important liquid, and it makes up a large percentage of the total emanation. The solids are chiefly chlorides and sulphates of the alkalies and alkaline earths and of iron, together with a much smaller quantity of metals and mineralizers.

THE PREMIER DIAMOND MINE, TRANSVAAL, SOUTH AFRICA.[1]

R. A. F. Penrose, Jr.

GENERAL FEATURES OF DIAMOND DEPOSITS IN SOUTH AFRICA.

Chief Localities.—The principal diamond mines of South Africa, locally known as diamond "pipes," are at and near Kimberley and elsewhere in Cape Colony; at a number of places in Orange River Colony; and near Pretoria in the Transvaal. The largest and most productive of these mines are those of the DeBeers Consolidated Mines Company near Kimberley, and that of the Premier (Transvaal) Diamond Mining Company near Pretoria. Diamonds have been found in other localities than those mentioned, but the production from them has not yet become of great importance. This is especially true of Rhodesia, where a number of diamond discoveries have been made, but the industry there is still in a very undeveloped condition.

Besides the mines mentioned, diamonds occur in the alluvium of the Vaal River, the Orange River and other streams of South Africa, but the production from such sources is very small compared with that from the so-called "pipes."

Mode of Occurrence.—The diamonds in most of the districts occur in a very similar manner, though sometimes the conditions are modified by local surroundings. The mode of occurrence is usually in association with necks or "pipes" of a rock of igneous or hydro-thermal origin, coming up through other rocks of various geological ages and of various lithological character. These "pipes" tend toward a vertical position, though sometimes they vary slightly from the vertical, and sometimes they

[1] During a trip in 1906 to South Africa, the writer visited a number of the larger diamond mines of that region. The present article, however, with the exception of references to the general features of other mines, relates especially to the Premier mine in the Transvaal.

alternately bulge and contract. They are usually of a roughly circular shape in cross section, though sometimes elliptical or irregular. They vary in diameter from a few feet to many hundreds of feet. Sometimes the "pipes" become elongated and partake of the nature of dikes, but the dikes are usually short lateral extensions of "pipes," or sometimes connect "pipes," and are not of common occurrence. As regards the depth of the "pipes," it may be said that, at Kimberley, mining has been carried on to a depth of over 2,500 feet, and the "pipe," as well as the diamonds, still continues downwards.

The mass of the filling of the "pipes" consists of a highly altered material converted largely to serpentine, and carrying fragments of country rock. These fragments have been taken up from the formations through which the "pipes" have passed, and vary accordingly in different districts. The serpentine material, however, is often very similar over widely separated areas. It is fragmental in character, of a soft chalky consistency and disintegrates readily on exposure to air. It is of a bluish or greenish gray color and is commonly known to the miners as "blue ground." The degree of alteration to serpentine is extensive, yet many of the original minerals, as well as products of alteration, can be identified. Among the most common minerals besides serpentine, are olivine, enstatite, bastite, hypersthene, chrome-diopside, garnet, ilmenite, biotite, vaalite, magnetite, epidote, apatite, calcite, zeolites and various other minerals in small quantities, such as rutile, chromite, tourmaline, corundum, cyanite, barite, etc. The different minerals vary somewhat in quantity in different "pipes." The serpentine, which now composes most of the mass, has probably been derived from the alteration of olivine, which once formed the chief constituent of the material, and perhaps in some cases from the alteration of the olivine-bearing rock known as peridotite. On the surface, the "blue ground" assumes a yellow or brown color due to the oxidation of iron-bearing minerals. The diamonds from certain mines often have characteristics which distinguish them from diamonds from other mines even in the same neighborhood.

FIG. 28. Open workings at the Premier Diamond mine, Transvaal, South Africa.

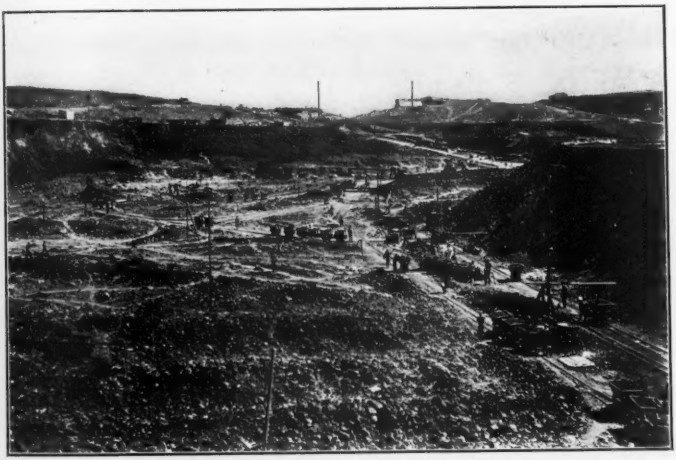


FIG. 29. Open workings at the Premier Diamond mine, Transvaal, South Africa.

Many "pipes" such as those described occur, but not all of them contain diamonds. Some seem to be entirely barren of diamonds, though the constituents of the "blue ground" may be the same as in the diamond-bearing "pipes." Other "pipes" contain a few diamonds, but not enough to work profitably; others contain enough to give a small profit; while a few give a very great profit. The discovery of a diamond mine, therefore, does not depend simply on the discovery of a "pipe" of "blue ground," but also on the discovery of diamonds in the "blue ground."

THE PREMIER DIAMOND MINE.

Location.—Among the more recently discovered of the diamond mines of South Africa, and yet one that has proved of enormous value, is the Premier mine in the Transvaal, belonging to the Premier (Transvaal) Diamond Mining Company. It was discovered in 1902 by Mr. T. M. Cullinan, and is situated about twenty-four miles in a northeasterly direction from the city of Pretoria, on the divide between the Elands and the Pinaars Rivers.

Mode of Occurrence.—The Premier "pipe" is situated on a rocky ridge, and the "blue ground," being soft and more easily eroded than the surrounding rocks, occupies a sag on the crest of the ridge, while the harder materials form low rocky hills around it. The rocks of the neighborhood are mostly quartzites with shales, and with intrusive sheets and masses of diabase, felsite, and other igneous materials, though the rock immediately surrounding the "pipe" on the surface is mostly felsite. These rocks are classed by the South African geologists as the Pretoria series and belong to the Paleozoic age.[1] Along the beds of streams running from this ridge, diamonds have been extensively mined in the alluvium, having probably come from the erosion of the "pipe" above.

The Premier "pipe" is oblong in cross section, being over a half mile in its longest direction and over a quarter mile in the widest place, and covers about eighty acres of ground. It is one

[1] Hatch and Corstorphine, "Geology of South Africa," 1895, pp. 170–178.

of several diamond-bearing "pipes" in this neighborhood, and is the largest of any yet discovered in Africa. The rock containing the diamonds (the "blue ground") has been oxidized near the surface and converted to a yellowish brown mass for a depth of from thirty to fifty feet, when the characteristic bluish or greenish gray color appears. This "blue ground" is a highly serpentinized fragmental material containing numerous pieces of country rock taken up from the formations through which the "pipe" has passed. It is classed by Messrs. Kynaston and Hall[1] as a highly serpentinized peridotite breccia with foreign fragments; and in it olivine, in a more or less altered condition, is still found, together with hypersthene, chrome-diopside, garnet, ilmenite, vaalite, calcite, zeolites, apatite, diamonds and other minerals. Ilmenite is very abundant and is known by the miners as "carbon," because the crystals and fragments in which the mineral occurs have something the appearance of fragments of charcoal. The chrome-diopside, though not very abundant, is conspicuous by its brilliant green color. The garnets are often of a beautiful ruby color.

The fragments of country rock included in the "blue ground" are quartzite, sandstone, grit, felsite, diabase, and possibly other rocks. Many of them appear to have come from the Pretoria series, and though the "pipe" on the surface is largely in felsite, yet it has probably passed through quartzite and other rocks below, from which it has taken up many of the fragments mentioned. Some of the fragments of sandstone and grit are supposed to belong to the Waterberg series, which is geologically above the Pretoria series. It is possible that the strata of the Waterberg series may have overlaid the present surface rocks when the Premier "pipe" was formed, and the fragments of Waterberg rock may have gotten into the "pipe" at that time; while later on, the Waterberg strata may have been eroded in this locality, exposing the rocks of the Pretoria series, which form

[1] "The Geological Features of the Diamond Pipes of the Pretoria District," Report of the South African Association for the Advancement of Science, 1904, p. 195.

the present surface.[1] This supposition is rendered still more probable by the occurrence of strata of Waterberg sandstone in situ a short distance from the Premier mine.

The diamonds are crystallized in isometric forms, octahedra, with more or less modifications, being common. The crystals are sometimes distorted, and broken crystals are not uncommon. The diamonds are white, pink, yellow, blue and other colors, and are of various sizes from the fraction of a carat to over 3,000 carats in weight. The largest diamond ever found in this mine, which is also the largest diamond ever found in the world, is known as the Cullinan diamond, and weighs 3,024¾ carats. It is in the form of a broken octahedron about four inches long, about two and a half inches wide and about two inches thick. The blue ground varies in different places considerably in its contents of diamonds, but it averages over half a carat per "load," and sometimes considerably more, a "load" being about sixteen cubic feet.

In the same general region as the Premier, are numerous other "pipes," some carrying enough diamonds to pay to work and others carrying too few to pay. Among them may be mentioned the Schuller No. 1 and 2, the Kaalfontein and the Montrose. The workings on the Schuller No. 1 are the oldest in this district and the mine was operated before the Boer War. None of these mines, however, compare in importance with the Premier.

Geological Age and Origin.—It is as yet impossible to determine the geological age of the Premier diamond "pipe," as well as that of other similar deposits in South Africa, except in a relative way. At the Premier mine, as elsewhere, it can be said that the "pipe" is necessarily younger than the youngest rocks through which it passes, but no direct evidence has yet been found to show how much younger it is. In the region of the Premier mine, the youngest rocks in which the "pipes" are now found are those of the Pretoria series, though they may once

[1] H. Kynaston and A. L. Hall, "The Geological Features of the Diamond Pipes of the Pretoria District," Report of the South African Association for the Advancement of Science, 1904, p. 188.

have intersected rocks of the Waterberg series.[1] In the Kimberley region the "pipes" appear on the surface in the still younger rocks of the Ecca series of the lower part of the Karroo system (Rhaetic). At the Monastery mine, in Orange River Colony, the "pipe" penetrates rocks of the Stormberg series of the upper part of the Karroo system. It is thus shown that some of the diamond-bearing "pipes" are at least younger than this horizon, but how much younger is not known. It is possible that some of the "pipes" may originally have passed through much younger rocks, which may once have overlaid those mentioned, and which have since been eroded, but as yet no direct proof of this has been found. On account of the marked similarity of composition and mode of occurrence of "pipes" in widely separated regions, it has been suggested by some that they were all formed at one general epoch, whatever that epoch may have been, but definite evidence to this effect is still lacking.

It is not intended here to discuss the origin of African diamond deposits, but a mention of some of the generally accepted ideas concerning them may not be out of place. The "pipes" are generally admitted to be of igneous or hydro-thermal origin, the opinion of most of those who have studied the subject being that they were forced up through the enclosing rocks something in the manner of hot mud springs or geysers. At their contacts with the surrounding country rocks, the latter are often upturned and generally more shattered and jointed than at a distance from the "pipes."

As yet no "pipes" have been found which show any signs of culminating in a crater, or of an overflow of any kind. They are all much alike in ending abruptly at the point where they reach the surface, their only marked effect on the topography of the country being frequently a slight depression or hollow, due to the fact that the material of which they are composed is more easily disintegrated by surface influences than the surrounding rocks. It has not yet been determined whether there was once a surface overflow which has since been eroded, or

[1] See description of the mine on a previous page.

whether such never existed. The "pipes" occur over widely separated areas, and so far as can be observed on the surface and in the mines, they are not dependent for their existence or for the nature of their contents on the age or character of any of the rocks through which they are seen to pass. It is possible, however, that at greater depths than have been explored, it might be found that the same, or a similar rock magma, has been the source of all of them.

It was suggested some twenty years ago by H. Carvill Lewis[1] that the diamonds were formed by the action of heat and pressure, within the "pipes," on hydrocarbons derived from carbonaceous shales. This idea was based on the fact that the diamond "pipes" in the Kimberley region passed through certain strata of carbonaceous shale on their way to the surface. Since then, however, other "pipes" carrying diamonds have been found in rocks which do not contain such carbonaceous shales, and below which no such shales, so far as known, occur in the geological series of the region. Hence, though perhaps as an abstract proposition it cannot be said that diamonds cannot sometimes be formed in this way, yet it appears that there must have been some other cause for their formation, especially in regions where these shales do not exist.

Messrs. Hatch and Corstorphine[2] think that perhaps the diamonds were an original constituent of a highly basic rock from which the breccia, which now fills the diamond-bearing "pipes," was formed; and they present some strong arguments in support of this view. Subsequently this breccia was serpentinized into its present condition. A. W. Rogers[3] also believes that the diamond-bearing formation has been derived from a highly basic igneous rock which sometimes contained eclogites composed of pyroxene, olivine, ilmenite, biotite, garnet and other minerals in smaller quantities. T. G. Bonney[4] found diamonds in masses

[1] "On the Genesis of the Diamond," British Association for the Advancement of Science, 1886, p. 668.

[2] "The Geology of South Africa," 1905, pp. 298–299.

[3] "The Geology of Cape Colony," 1905, p. 350.

[4] "The Parent Rock of the Diamond in South Africa," *Proceedings of the Royal Society*, Vol. LXV., 1899, pp. 235–236.

of eclogite rock from the Newlands diamond mine in Orange River Colony, and he supposes that these were the source of the diamonds. From the rounded character of some of these eclogite masses, he supposes that they were water-worn pebbles and were derived from conglomerates through which the "pipes" had passed. Hatch and Corstorphine,[1] however, as well as Rogers,[2] believe that the eclogite masses were simply parts of the basic magma from which the diamonds and the breccia filling the "pipes" were derived. Gardner F. Williams,[3] for many years the well-known manager of the DeBeers Consolidated Mines Company, does not believe that any adequate explanation for the origin of the diamonds has yet been given.

Commercial Features.—The Premier mine, though one of the newest in South Africa, has, however, become one of the greatest, and its production is a most important element in the diamond market. The property is worked in large open cuts on the surface, as the operations have as yet not been carried on long enough to require any extensive underground mining such as is done at Kimberley. A few drifts and shallow prospecting shafts are the only underground work, and none of them are more than about one hundred feet deep. A diamond drill hole, however, of about one thousand feet has been sunk in the "blue ground." Steam shovels are extensively used in mining. The "blue ground" after being mined is crushed, washed, sized automatically, and then passed over inclined tables covered with grease. The rock fragments pass over the grease and are washed away at the ends of the tables, but the diamonds stick to the grease, and when they have collected in considerable numbers, they are picked off the tables, washed, sorted and prepared for market. At Kimberley and some of the older mines, the "blue ground" is not crushed as it is here, but is exposed to the air in a thin layer over wide areas of ground, called "floors," where it rapidly disintegrates. Then it is washed, sized, and passed over grease tables. On certain classes of diamond-bearing rock, hand

[1] "Geology of South Africa," p. 298.
[2] "Geology of Cape Colony," p. 350.
[3] "The Diamond Mines of South Africa," 1905, p. 510.

sorting is still practiced. This was, in the old days of diamond mining in Africa, the only method employed, but since the discovery of the use of grease tables at Kimberley some years ago, the latter method does away with much of the hand sorting. It is cheaper, quicker, and goes far to eliminate the loss by theft incident to the old method.

The production of the Premier mine since it was opened in 1902 up to October 31, 1905,[1] was 1,694,513¾ carats, valued at 1,998,152 pounds, 8 shillings and 9 pence, or almost $10,000,000. The value of the diamonds varies greatly according to size, color and other properties. From November 1, 1904, to October 31, 1905, the value of 75 per cent. of the diamonds mined averaged 52 shillings 6 pence per carat and the value of the remaining 25 per cent. averaged 9 shillings per carat. Large diamonds, however, or diamonds with exceptionally fine color and other characteristics may bring a very much greater price than the high average given above, while, on the other hand, exceptionally poor diamonds may bring a much lower price than the low average given above. The Transvaal government exacts a royalty of 60 per cent. of the net profits from all the diamonds mined, the company retaining only 40 per cent.

[1] Directors' Report, Third Annual Meeting of the Premier (Transvaal) Diamond Mining Co., for period ending October 31, 1905.

RECENT IMPROVEMENTS IN THE UTILIZATION OF COAL.

MARIUS R. CAMPBELL.

The better utilization of coal and the cheaper production of power are questions of vital interest to almost every person in the country, for the foundation of modern civilization is power, and the necessaries and comforts of life are dependent on it. Cheapening the cost of power will not necessarily directly decrease the cost of living, but the tendency will be in that direction and hence will be a welcome event. Ordinarily the geologist is not particularly interested in the question of the generation of power, but if the improvement tends to prolong the life of our coal fields, makes a marketable fuel out of what is now a waste-product of coal mining, or points out a way to utilize our great deposits of peat, the geologist can not be other than interested in the change.

During the last decade many improvements in the production of power have been suggested, among which producer gas and the gas engine stand forth preëminently as the most efficacious. To be sure, the use of producers and gas engines is not new. They have been in operation in this country for many years, but the utilization of soft coal and lignite, and even peat, in the manufacture of producer gas for *power purposes* is a novelty, and as such deserves special consideration.

Prior to the year 1904 no one in this country had succeeded in using soft coal and lignite in this way, and consequently the results obtained at the Fuel-Testing Plant of the United States Geological Survey at St. Louis are of the greatest interest, for in that plant such fuels have been used successfully for at least three seasons. The results of the operation of this plant during 1904 and 1905 are now published,[1] and it is easy for engineers

[1] U. S. Geological Survey bulletins 261 and 290 (261 out of print) and professional paper No. 48.

to see from the figures the results attained, but to the layman they are scarcely intelligible and need interpretation. The object of this paper is to present such an interpretation which will be so plain that "he who runs may read," and not only read but understand.

During the period of time covered by the reports mentioned above, seventy-two tests were made under practical conditions, in the producer plant on as many different samples of coal, ranging in quality from the brown, woody lignites of North Dakota and Texas, with a moisture content of from 35 to 40 per cent., to the best Virginia, West Virginia, and Pennsylvania semibituminous coals with a moisture content of little more than 1 per cent. and one test on machined peat. Only a few failures were made, and generally these were the result of the mechanical rather than the chemical condition of the coal.

The duration of the tests ranged from 10 to 72 hours; those made during 1904 were generally short, about 30 hours, but those made during 1905 were almost all of 72 hours duration,—long enough to develop approximately the efficiency of the coal and to prove the practicability of this method of use.

The work performed during these tests was all of the greatest interest because the method was new, and no one could say in advance what would be the result of any given test. Certain features, however, can be singled out as presenting particularly important and interesting points. One of these is the absence of all smoke. This alone would probably pay for the installation of the new type of machines in manufacturing plants in large cities and for war vessels. In the producer the fuel is burned, and the smoke is consumed or goes out as tar which is mechanically separated from the gas.

Another feature of great interest from an economic standpoint is the fact that coals with high percentages of impurities, such as sulphur and ash, can be used successfully, making excellent fuel for the producer. Coals carrying from a small fraction of 1 per cent. to 7.36 per cent. of sulphur were used, and ash as high as 23.44 per cent., gave excellent results. In fact, it

seems that coal containing ash up to 50 per cent., or even more, could be used, provided it did not form clinkers and was not so fine as to pack in the producer.

Another point of interest to the consumer is that in the producer, lump coal gives no better result than fine coal, provided the fragments are prismatic and not dust or plates. For use under the steam boiler the size of the coal is of great importance and slack and weathered (slacked) coal gives poor results. Their behavior in the producer is not well determined, but there is not so much difference in the results obtained from the different grades as there is in the generation of steam.

The following table shows graphically the results obtained both in the producer plant and in the steam plant, since most of the coals were tested in both ways. The first block of the diagram is the standard and represents one electrical horse-power per hour. The blocks in the left-hand column show the fraction of an electrical horse-power per hour that was produced by one pound of coal, as fired, under the steam boiler. The second column represents the fraction of an electrical horse-power per hour generated by one pound of coal, as fired, in the producer-gas plant. The relative efficiency of the coal used in the producer plant as compared with its use under the steam boiler is shown by the size of the blocks and by the ratios in the central column.

Tests numbered 12, 22, 24, 26, 29, 31, 37, 38, 45, 49, 50, 56, 58, 59, 60, 61, 62, 63, 64, 65, 69 and 73 represent results obtained in 1904 when short tests were run, and in many cases they may not show the true efficiency of the coal.

A striking feature of this table, and the one that shows the great importance of the process, is the comparative value of the results obtained in each type of plant: thus in every case the power produced by one pound of coal in the producer is many times the power produced by the same amount of coal in the steam plant. The ratios of these results run from 1.96 to 3.34; that is, the very best West Virginia coal yielded practically 3⅓ times the amount of power when used in the producer

that it did in the steam plant, and the very poorest coal yielded in the producer practically double the amount of power that it did in the steam plant.

The next notable feature of the diagram is the fact that in the producer, North Dakota and Texas brown lignite and Florida peat yielded more power than the very best West Virginia coal under the steam boiler. The former gave values of .299, .308, .309, .355, .388 and 330 in the producer, whereas the very best West Virginia coal yielded only .287 of an electrical horse-power under the steam boiler.

In explanation of the results given above, it may be said that the apparatus used in both the steam and producer plants was not of the highest type. Thus if the steam engine had been of the compound condensing type, probably 50 or even 100 per cent. could have been added to the results obtained, but even such a percentage of increase would not make the steam results comparable with the producer-gas results. It must be granted that the efficiencies of the fuel could have been greatly increased by a better type of steam apparatus, but also it must be remembered that the producer and gas engine used in these tests are now practically obsolete and better results could probably have been obtained in this plant with better apparatus. In view of these conditions the results of the tests may be considered fairly comparable.

The economies shown in the diagram are so great that it is only a question of time until this mode of generating power will supersede steam. It will not come at once, because both the producer and the gas engine are passing through a stage of development when changes are so rapid that what is consiered the highest type this year is discarded next year for a new model. This change may not be all in the line of improvement, but the net result is a gain and the efficiencies obtained now can always be duplicated and probably in the future can be very much improved.

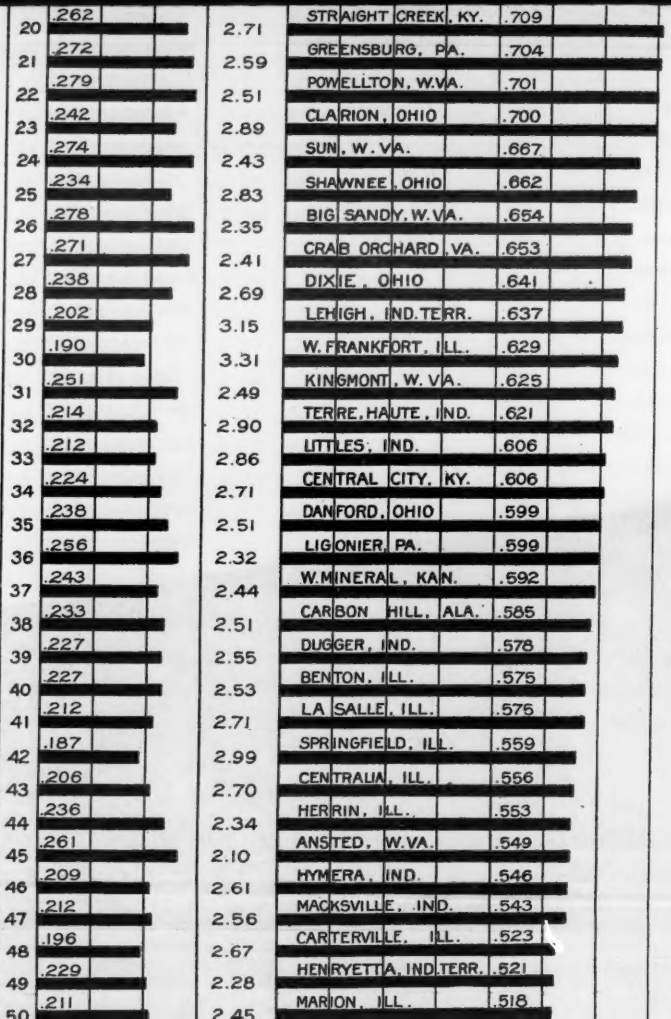
The tests at St. Louis were all made on a forced-draft type of producer in which tar is saved as a by-product, but so far no

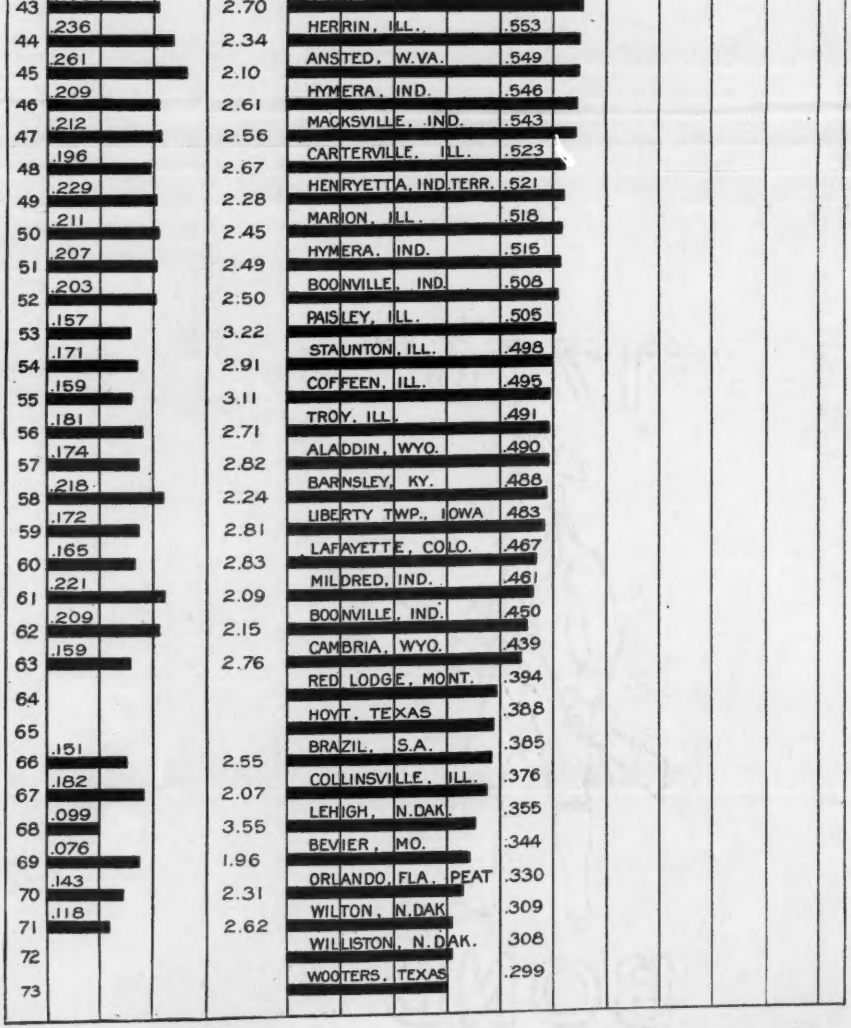
PLATE II. ECONOMIC GEOLOGY.

TABLE SHOWING THE RELATIVE EFFICIENCIES OF COALS

TABLE SHOWING THE RELATIVE EFFICIENCIES OF COALS USED UNDER THE STEAM BOILER AND IN THE PRODUCER PLANT AT THE U.S. GEOLOGICAL SURVEY FUEL TESTING PLANT, ST. LOUIS, MO.

	STEAM		PRODUCER GAS ONE ELECTRICAL HORSE POWER	
1	.287	3.34	PAGE, W.VA.	.961
2	.276	3.29	PAGE, W.VA.	.909
3	.275	3.03	GLEN ALUM, W.VA.	.883
4	.279	2.60	TOMS CREEK, VA.	.826
5	.246	3.20	RUSH RUN, OHIO	.794
6	.273	2.86	ELLSWORTH, PA.	.781
7	.285	2.74	EHRENFELD, PA.	.781
8	.249	3.10	NEFFS, OHIO	.770
9	.265	2.88	DARBY, VA.	.763
10	.281	2.71	ACME, W.VA.	.763
11	.278	2.72	BRUCE, PA.	.758
12	.269	2.82	BREITZ, W.VA.	.758
13	.270	2.79	PAINTSVILLE, KY.	.752
14	.246	3.04	BRADLEY, OHIO	.746
15	.256	2.85	E. MILLSBORO, PA.	.730
16	.262	2.77	CRAB ORCHARD, VA.	.725
17	.223	3.22	ZEIGLER, ILL.	.719
18	.279	2.59	BIG BLACK MT., KY.	.719
19			MONONGAH, W.VA.	.714
20	.262	2.71	STRAIGHT CREEK, KY.	.709


20 .262 2.71 STRAIGHT CREEK, KY. .709
21 .272 2.59 GREENSBURG, PA. .704
22 .279 2.51 POWELLTON, W.VA. .701
23 .242 2.89 CLARION, OHIO .700
24 .274 2.43 SUN, W. VA. .667
25 .234 2.83 SHAWNEE, OHIO .662
26 .278 2.35 BIG SANDY, W. VA. .654
27 .271 2.41 CRAB ORCHARD, VA. .653
28 .238 2.69 DIXIE, OHIO .641
29 .202 3.15 LEHIGH, IND. TERR. .637
30 .190 3.31 W. FRANKFORT, ILL. .629
31 .251 2.49 KINGMONT, W. VA. .625
32 .214 2.90 TERRE HAUTE, IND. .621
33 .212 2.86 LITTLES, IND. .606
34 .224 2.71 CENTRAL CITY, KY. .606
35 .238 2.51 DANFORD, OHIO .599
36 .256 2.32 LIGONIER, PA. .599
37 .243 2.44 W. MINERAL, KAN. .592
38 .233 2.51 CARBON HILL, ALA. .585
39 .227 2.55 DUGGER, IND. .578
40 .227 2.53 BENTON, ILL. .575
41 .212 2.71 LA SALLE, ILL. .576
42 .187 2.99 SPRINGFIELD, ILL. .559
43 .206 2.70 CENTRALIA, ILL. .556
44 .236 2.34 HERRIN, ILL. .553
45 .261 2.10 ANSTED, W.VA. .549
46 .209 2.61 HYMERA, IND. .546
47 .212 2.56 MACKSVILLE, IND. .543
48 .196 2.67 CARTERVILLE, ILL. .523
49 .229 2.28 HENRYETTA, IND. TERR. .521
50 .211 2.45 MARION, ILL. .518


43 .236 2.70 HERRIN, ILL. .553
44 .261 2.34 ANSTED, W.VA. .549
45 .209 2.10 HYMERA, IND. .546
46 .212 2.61 MACKSVILLE, IND. .543
47 .196 2.56 CARTERVILLE, ILL. .523
48 .229 2.67 HENRYETTA, IND. TERR. .521
49 .211 2.28 MARION, ILL. .518
50 .207 2.45 HYMERA, IND. .515
51 .203 2.49 BOONVILLE, IND. .508
52 .157 2.50 PAISLEY, ILL. .505
53 .171 3.22 STAUNTON, ILL. .498
54 .159 2.91 COFFEEN, ILL. .495
55 .181 3.11 TROY, ILL. .491
56 .174 2.71 ALADDIN, WYO. .490
57 .218 2.82 BARNSLEY, KY. .486
58 .172 2.24 LIBERTY TWP., IOWA .483
59 .165 2.81 LAFAYETTE, COLO. .467
60 .221 2.83 MILDRED, IND. .461
61 .209 2.09 BOONVILLE, IND. .450
62 .159 2.15 CAMBRIA, WYO. .439
63 2.76 RED LODGE, MONT. .394
64 HOYT, TEXAS .388
65 .151 BRAZIL, S.A. .385
66 .182 2.55 COLLINSVILLE, ILL. .376
67 .099 2.07 LEHIGH, N.DAK. .355
68 .076 3.55 BEVIER, MO. .344
69 .143 1.96 ORLANDO, FLA. PEAT .330
70 .118 2.31 WILTON, N.DAK. .309
71 2.62 WILLISTON, N.DAK. 308
72 WOOTERS, TEXAS .299
73

method has been devised of utilizing the tar. It is the opinion of those best qualified to speak, that this type of producer will not be satisfactory for soft coals and that the producer of the future will consume all tarry matter, making a lower-power gas but generating a much greater volume than the producer in use to-day. Great uncertainty is also felt about gas engines in large units, and probably they will not be used extensively until they have reached a better stage of development.

These objections can only delay; they do not touch a vital point in the method. As soon as they are answered the producer and the gas engine will take the place of the reciprocating engine and even of the turbine, except where especial conditions made the latter desirable.

THE OXIDATION OF PYRITE.

ALEXANDER N. WINCHELL.

The theory of the secondary enrichment of copper ores may be said briefly to involve oxidation, solution, transportation, reduction and deposition. The oxidation involved is usually the alteration of pyrite, although other sulphides are doubtless subject to the same change. The oxidation of pyrite is supposed to yield ferrous sulphate and free sulphur dioxide, or free sulphurous acid, according to the reaction:

$$FeS_2 + H_2O + 6O = FeSO_4 + H_2SO_3.$$

Further oxidation would lead to the formation of ferric sulphate and sulphuric acid. The solution of copper minerals as copper sulphate is a natural result of the presence of free sulphurous or sulphuric acid, and iron sulphate, in the percolating waters which accomplish these changes. The transportation of the copper in solution carries it from the zone of oxidation to the lower depths where reduction occurs. The reduction of copper sulphate through the agency of pyrite, and its deposition as copper sulphide, have been experimentally demonstrated by H. V. Winchell.[1]

It is evident then that the theory of secondary enrichment involves two assumptions that should be capable of experimental proof; the first is that natural circulating waters will oxidize pyrite, and the second is that some natural agent or agents found in mineral veins will reduce and precipitate copper from its solution as a sulphate. As mentioned above, the second assumption has received its demonstration; it is the purpose of the present paper to describe an attempt to produce experimental evidence of the accuracy of the first assumption.

[1] "Synthesis of Chalcocite, and its Genesis at Butte, Montana," *Bull. Geol. Soc. Amer.*, XIV., 269.

It should be stated at once that the writer considers the field evidence of the oxidation of pyrite to be amply sufficient to demonstrate its occurrence in nature. The problem remains, however, to determine, as nearly as may be, the conditions under which the process may occur, and the approximate rate at which it proceeds.

The natural conditions under which oxidation occurs are well known. It is a process produced by the action of descending meteoric waters, which, as rain, are free from dissolved salts, but contain some gases in solution, especially oxygen, nitrogen, and carbonic acid. In general it may be assumed that negligible quantities of dissolved salts are present in the waters when they first reach the pyrite. If this be true, water containing nothing but dissolved gases should be sufficient to oxidize sulphide of iron. The problem thus resolves itself into the question as to whether pure water charged with gases by aeration will attack pyrite.

The apparatus used to attack the problem consisted of a large glass vessel three fourths filled with distilled water, above which was suspended an aluminum wire screen supporting powdered

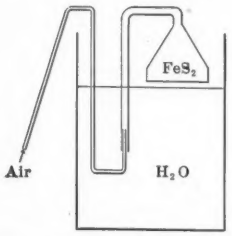


FIG. 30. Apparatus for Oxidation of Pyrite.

pyrite. Further, the water was aerated, and at the same time kept in circulation, by means of an air blast passing through a glass tube which terminated below the surface of the water inside a larger glass tube leading upward and discharging upon the pyrite. The arrangement of the apparatus is shown in the accompanying drawing (Fig. 30). The whole apparatus was

kept constantly covered with an ordinary cloth to keep out the dust, but it was not expected nor desired to keep out such impurities as might be present in ordinary air, since these would be present in the water active in the process in nature. Additional distilled water was added from time to time to replace that which escaped by evaporation.

The pyrite used was obtained from the first level of the Pennsylvania mine in Butte, Montana. Marcasite is common in the Butte mines; therefore it should be mentioned that abundant evidence of isometric crystallization was found on the material used. An analysis of the mineral was carried out by Mr. Albert O'Brien under the direction of the writer. It resulted as follows:

Fe	46.80
S	53.18
Cu	trace
Total	99.98

Repeated attempts were made to determine the copper, but the amount was too small; in fact, in some assays not even a trace was detected. The pyrite was therefore very pure.

In the experiment there were used three hundred grams of pyrite which had been ground to pass a twenty-mesh screen and had been caught on a forty-mesh screen.

The percolation of aerated water through the powdered pyrite was allowed to continue for some time; at the end of one month qualitative tests failed to show the presence of any iron, or sulphate, or acidity in the water. At the end of three months some iron and some sulphate were positively identified in the water, but the amounts were so small that satisfactory quantitative tests were not obtained. At the end of ten months a careful analysis of the water yielded the following results:

Ferric iron	7.75 mg. per liter.
Ferrous iron	trace
SO_4	25.5 mg. per liter.
SO_3	trace

It therefore appears that under the conditions of the experiment oxidation is practically complete; these conditions supply

abundant oxygen, undoubtedly much more than would be present in nature. These conditions should result not only in more complete but also in more rapid oxidation of the pyrite in the experiment than in nature. Ferrous sulphate and sulphurous acid probably would be the chief products formed in nature.

An aluminum wire screen was used in the experiment to support the powdered pyrite because it was thought that that metal would not be attacked by the water or the oxidation products which could be expected. Nevertheless, an appreciable quantity of aluminum was found in solution in the water at the close of the experiment. The writer has no positive information on the subject, but he considers it improbable that small quantities of aluminum sulphate in solution would affect the rate of oxidation of the pyrite. In any event, it may be said that, if the aluminum affected the problem in any way, the same effect might easily occur in nature.

The results of the analysis given above may be recalculated as follows:

$Fe_2(SO_4)_3$	27.68	mg. per liter.
H_2SO_4	5.7	mg. per liter.
Total Fe	93	mg.
Total $Fe_2(SO_4)_3$	.332	mg.
Total H_2SO_4	68	mg.

The experiment, then, demonstrates that pure water charged only with air—ignoring the small amount of aluminum—is sufficient to produce oxidation of pyrite. But it is perhaps more important that we also have evidence that simple oxygenated water attacks iron sulphide very slowly. In fact, water percolating through three hundred grams of powdered pyrite constantly for ten months dissolved in that time only one fifth of a gram of pyrite (0.093 grams of iron), or one fifteenth of one per cent. of the whole. And this, in spite of the fact that the conditions of the experiment, on account of the abundance of oxygen, favored an oxidation much more rapid than would probably occur in nature.

It appears from experience in wet methods of extracting cop-

per at the Rio Tinto mines[1] that copper is oxidized and taken into solution much more rapidly from the compound Cu_2S than from the compound CuS; and that it is even much more slowly dissolved from the compound $CuFeS_2$. From these results and those of the foregoing experiment it seems to be open to question whether the oxidation of pyrite is a necessary preliminary to that of copper compounds. Inasmuch as chalcocite seems to oxidize much more rapidly than pyrite, may it not be that its solution precedes and perhaps hastens the oxidation of pyrite in nature? Further investigation seems to be needed along this line.

[1] C. H. Jones, *Trans. Amer. Inst. Min. Eng.*, 1905, XXXV., p. 3.

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, South Bethlehem, Penna. The full name of the author should be attached to all communications.

HOW SHOULD FAULTS BE NAMED AND CLASSIFIED?

Sir:—In responding to your invitation to contribute to the discussion of Mr. Ransome's paper, "The Directions of Movement and Nomenclature of Faults," I desire first to express my appreciation of the service which Mr. Ransome has rendered in calling attention to the indefiniteness of the purely mechanical phenomena. His statement invites a reconsideration of the first principles and prescribes caution in the interpretation of strictly local relations; and founded as it is upon refined and detailed observations, it commands the thoughtful consideration of all those who approach the tectonic problem earnestly with a view to its solution.

I recognize the value of Mr. Ransome's inductive method and the correctness of his conclusions, but to pursue the discussion I venture to proceed in a measure deductively, hoping thus to gain the advantage of a somewhat different point of view.

Somewhat extended observation of districts and provinces in which normal faulting is a prominent type of structure has led me to entertain favorably the hypothesis that such phenomena are characteristic of regions which have been superelevated; that is, districts raised above a position of adequate support. We need not speculate how such superelevation is brought about, or what is the nature of adequate or inadequate support, although in fuller discussion such consideration would be essen-

tial. It is, however, a fact that if we endeavor to restore a system of normal fault blocks to the relations which they may have had before faulting, we must commonly construct a dome-shaped figure of some sort, whose surface occupies more space than the displaced blocks occupy. That is to say, in any cross section an elongated arc has in consequence of faulting been brought into a shorter chord, commonly by bringing the narrower parts of wedges into juxtaposition. There may be many apparent exceptions, but in those districts which have seemed to afford the most detailed information the above conclusion appears to hold.

If now we analyze the sequence of stresses which must arise in a mass thus deformed, it will be seen that the doming may produce elongation or stretching in superficial sections at least, and thus tend to provide the opportunity for the development of planes whose attitude is that of the normal fault plane. In so far as the inadequacy of support gives rise to vertical displacements *pari passu* with the stretching, the blocks will adjust themselves with reference to each other by relative displacement in the direction of maximum stress and least resistance. It is obvious that the actual resultant motion may frequently be diagonal to the vertical, although commonly steep, as it is under the control of gravity. The horizontal and vertical components of the motion are, however, those which we most readily observe. In this process elongation is the primary condition, and a settling down of the blocks is a result. Through that settling, a secondary effect of compression is set up. The large masses become wedged against one another, and as their magnitude is such that their own weight is sufficient to deform them, they suffer more or less folding and even reversed faulting as an after effect.

It seems if this analysis be at all correct that we may reasonably expect to find some reversed faulting in connection with normal faulting wherever the latter is developed on a truly large scale. The absence of folding or reversed faulting could only follow in case the blocks were free to move outward to the ex-

tent demanded by the elongation due to the attitude of the normal fault planes.

The sequence of phenomena which I have suggested should not be confused with those of regions in which compression produces folding and thrusting as immediate effects of the initial stresses. Such phenomona appear to me to belong in a totally different category from those of normal faulting and the type of reversed faulting associated with it.

In regard to nomenclature, it seems to me there is oportunity to use the familiar terms in a somewhat precise manner which conveys desirable distinctions. Thus the term *normal* expresses to the reader a definite mechanical relation of the displaced parts so far as they can be observed, but is without any necessary connotation with a theory of the precise direction or cause of movement. The term *reverse fault,* which was initially applied in contradistinction to a normal fault, seems to me to have an equally clear meaning of mechanical relations and to be free from undesirable theoretical postulates. The two terms appear to satisfy the requirements of purely descriptive writing as applied to particular localities. When, however, the treatment is one with reference to causal conditions, the phrase *tension fault* may become desirable to indicate the more or less hypothetical nature of the stress that gave rise to the dislocation. On the other hand, *thrust, overthrust,* and *compression fault* serve the purposes of discussion in fields where the peculiar phenomena of normal faulting are not involved, or if involved are clearly of a later and distinct episode of deformation.

Referring to Mr. Ransome's suggestion that a careful study of faults may greatly lessen the apparent preponderance of normal faults and bring the general phenomena of faulting more into harmony with the evidence of dominant compressive stresses in the lithosphere, I would like to emphasize the point that sometimes we plainly have to deal with displacements whose general cause is gravity, and other times with other displacements whose general cause is compressive tangential stress; and that any attempt to force the phenomena of one mode of deformation

into the category of the other must result in confusion. Not only are the effects due to different causes, but they appear to have developed at widely separated times and in regions which were peculiarly situated at a special time, so that the conditions favored the particular type of deformation which developed. Thus, in North America, the Great Basin region was strongly compressed in a geologic period which long preceded the epoch of Tertiary and Quaternary normal faulting. The same is true of the Asiatic continent, where Permo-Mesozoic diastrophism took the form of general and intense compression, whereas late Tertiary and Quaternary diastrophism is of the nature of normal faulting and warping on a stupendous scale. It is important in the study of diastrophism in general, and of the dynamics of the lithosphere, to keep the concepts of vertical warping and displacement distinct from the concepts of horizontal folding and thrusting.

Finally, I desire to throw out as an inquiry worthy perhaps of consideration on the part of geologists studying the economic side of this problem, the question whether the genetic conditions of normal faulting are specially favorable to mineralization. It has seemed to me that superelevated areas, such as I have postulated as an initial condition of normal faulting, are frequently highly mineralized areas; and that it is possible that the subterranean conditions which give rise to the initial doming may be specially favorable to the activity of mineralizing agents.

BAILEY WILLIS.

WASHINGTON, D. C., February 11, 1907.

Sir:—The subject of faulting is of such fundamental importance in the science of economic geology that the discussion recently inaugurated by Ransome[1] should be made exhaustive. In this discussion the two necessary correlative parts for best results must be kept clearly distinct. It becomes first necessary to make a critical examination of all the facts and theories germane to the subject, to be followed by a synthetic or constructional

[1] F. L. Ransome, "The Directions of Movement and the Nomenclature of Faults," ECONOMIC GEOLOGY, Vol. I., No. 8, p. 777.

part, giving us, or at least clearly leading to, a proper conception of faulting and a scientific nomenclature. At present this can best be done informally, in order that more facts pertinent to the matter can be brought forth from various sources.

That there is a great lack of an adequate conception of faults is beyond question. As Ransome notes rather in full, the standard writers, as well as all others, pass lightly over the subject, as a simple one not necessitating extended treatment. This condition of affairs is due to a too great, though perhaps a natural, extension of the inductive method, with the result that some vital, but not strikingly apparent, facts have been eliminated by neglect. In other words, we have failed to understand all the causes of faulting, so that our criticism must be mainly with questions of genesis. Recent studies have done, and are doing, much to throw light on this point, by developing new facts which call for explanation. As Ransome has well pointed out, the horizontal element in faults is of the greatest importance, and yet it has received practically no notice. This element is but one of many which call for a re-examination of the whole subject.

Among the many false assumptions made, though largely unconsciously, in studying faults, there are two important ones upon which all the others, to a greater or less extent, depend. These are: (1) That gravity, acting downward, and lateral pressure, acting horizontally, or nearly so, are the causes of faults; and (2) that rocks are homogeneous in strength rather than heterogeneous. The important corollaries deduced from these, though they do not necessarily hold true for all cases, are (1) that the direction of motion is up or down, with commonly a secondary horizontal displacement due to the dip of the fault-plane; (2) that a fault-plane is truly a plane; and (3) that normal faulting denotes tension and produces areal extension of the crust, and reverse or thrust faults denote compression and produce areal contraction of the crust. Attention needs also to be directed to the common assumption that the force producing faulting remains practically unchanged in direction.

Among the great number of faults studied in mining dis-

tricts in this country, a large proportion have shown a horizontal component of motion more important than a vertical one. In the writer's own experience, in those faults examined in which the direction of motion could be ascertained, the horizontal component was the more important.

In case of so-called pivotal faulting the rotation about some axis which is not necessarily at right angles to the fracture plane is due to three possible causes, acting alone or together: (1) An actual increase of friction at some point or area of the fault plane; (2) fracture planes so warped that the walls twist relative

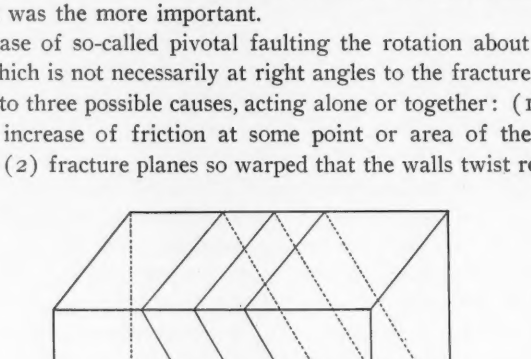


FIG. 31. Stereogram showing ideal relations of hanging wall block of the Comstock Lode. The motion of rotation is due to the warping of the fracture planes which are transverse to the main fault. The axes of rotation are not exactly at right angles to the main fault planes, due to the slight warping of the latter.

to each other; and (3) such a condition that the line of the force does not act through the center of inertia of the crust block. The word "force" of course stands for the resultant force. As an example of the first cause are those occurrences of step faults, each step of which has rotated as well as moved up and down relative to the adjoining blocks. Fine examples of this occur in some of the Great Basin ranges, in which the top of each step now lies at some angle with the original nearly plane surface of which it originally formed a part, and with the top surfaces of all the other step blocks. As a type of the second cause, the faulting exhibited by the hanging wall block of the Comstock Lode is a splendid example. Here the hanging wall has dropped relative to the foot, and has also been twisted clock-wise about an imaginary axis lying somewhere near the surface. This torsional strain has aided in producing the openings which were later filled by the very rich ores. A stereogram, Fig. 31, is given of this block, expressing ideal relations. Note that the axis of rotation is not at right angles with the fault-line, though nearly so. Of the third cause, no carefully studied examples appear to exist. However, sufficient has been written, and sufficient has been seen by the present writer in the way of traces of gently curved striations, *et cetera,* to warrant the statement that the conditions necessary for such cause to act are common. A further reference will be made to this. There is another important point to be noted in regard to these pivotal faults. If, with a fault-plane not vertical, the motion of rotation has been large compared to the motion of translation, both normal and reverse faults will be produced on either side of the axis of rotation. This feature is particularly important when a certain very important cause of faulting is later introduced.

Both normal and reverse faults occur together in many areas, as noted by Ransome.[1] There are two phases of this occurrence, granting the same age to both types. First, the two classes of faults may be of different magnitudes. This is very common, and yet it is difficult to find much notice of the details of such cases.

[1] F. L. Ransome, *op. cit.,* p. 781.

Hence two somewhat peculiar examples are given. One, in outline, is from the Mother Lode region of California, Fig. 32, as typical of a country closely compressed nearly horizontally. The motion, apparently normal faulting with secondary reverse faulting, is due primarily to lateral pressure *not* horizontal, with a slightly shifting position (forces 1 and 2, shown by arrows). This lateral pressure is due largely to a force 0, acting vertically upward at some distance to the eastward. This arrangement of

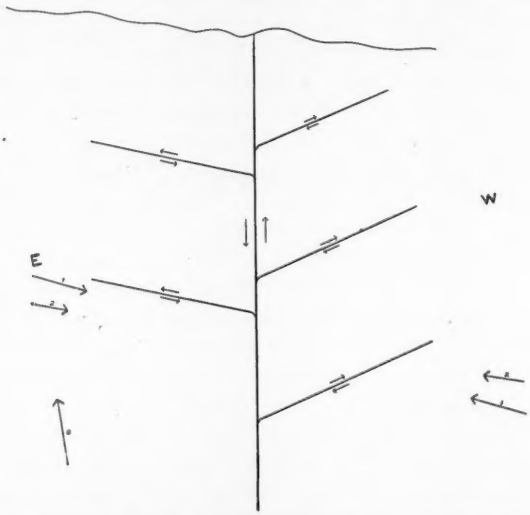


FIG. 32. Outline of faults in amphibolite schist near the Mother Lode, California. Force 0 is a force producing just sufficient motion of rotation to cause a shifting of force 1 to the position of force 2.

forces is in accordance with observed facts of geologic structure. The example shows well the results of changing directions of force. Every fault is the result of a number of proximate forces, each variation of which induces a change in direction and intensity of the resultant force. This change may in its turn induce secondary faulting, as in Fig. 31, or a variation in the nature or direction of the original fault. The second and much

finer example is given in astereogram (Fig. 33). This faulting has been noted by the writer near Carson City, Nevada. It serves the triple purpose of showing faults of different magni-

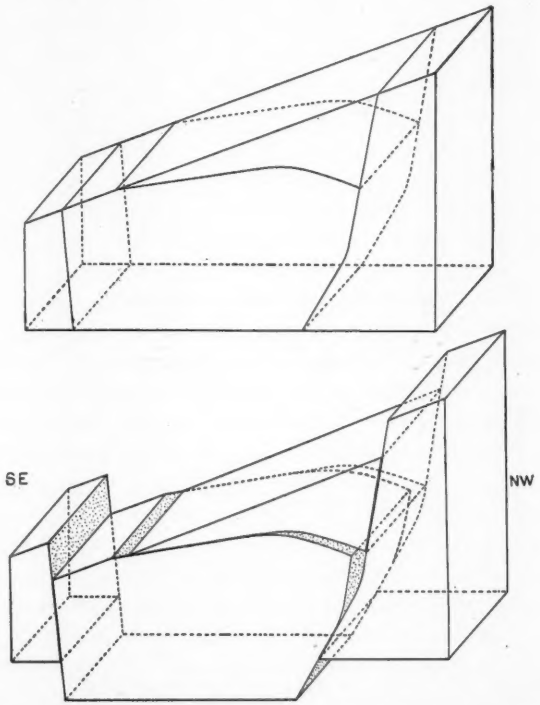


FIG. 33. Stereogram of faulted block near Carson City, Nevada. The line observation lies just below the curve of the nearly horizontal fault. The normal fault on the south is entirely inferred. As is to be expected from the figure, the thin edge of the top fault block is badly brecciated. Also, the open spaces between the blocks do not remain in this condition, but are filled with material from the walls.

tudes, of exhibiting warped fault planes, and of proving that one fault may at the same time be both normal and a reverse.

Second, both types of faults appear together and of the same

order of magnitude, in such manner that it is extremely difficult, if not absolutely impossible, to imagine them of different ages. Granting only the two proximate causes of faults, tension and compression, there are several ways of accounting for these occurrences. For instance, a thrust from below vertically upward will project a wedge-shaped block up, forming normal faults, and locally extending the area of the crust. This local extension will elsewhere be neutralized by thrust or reverse faults. Or again, contrary to a common assumption that the stresses producing faults lie in planes parallel to the earth's surface, these forces are in a plane lying at some angle with the horizontal, so that many of what seem to be normal faults or reverse faults are not intrinsically such (see Fig. 31). And lastly, is a condition very common in the volcanic region of the Great Basin, under which the crust has been broken into a great complex of blocks, the *tilting* of which has produced both normal and reverse faults of equal magnitude. Here we come face to face with the root of the difficulty, the question of genesis.

It is obvious that neither simple gravity nor tangential compression will serve to produce all the results noted. In our assuming that faulting is a relatively simple process we have badly mixed proximate causes with ultimate causes, and proximate effects with ultimate effects. A normal fault has caused indisputably a *local* extension of the crust, but such a fact alone does not warrant the belief that the faulting of the same age in the region containing this fault has caused crustal extension and is due to rearrangement of blocks under gravitational stress. A reverse fault has undoubtedly caused *locally* a shortening of the crust, but this fact alone does not warrant the assumption that a force of horizontal compression has produced that fault, or that the major force acting throughout that particular region was one of compression. Therefore, in the light of the facts we must search for some other cause of faulting motion. From a careful study of the field relations in areas of faulting, one is irresistibly swept to the conclusion that the cause of faulting

in the Tonopah region, so admirably discussed by Spurr,[1] is of widespread application. And further, not only are the violent migrations of igneous material the cause of complex faulting, but also it is most reasonable to conceive that the deeper and more gradual movements of the subcrust are the cause of the larger fault systems. Spurr[1] notes this fact, and his conclusions are of the utmost importance, for he appears to be the first so clearly to have set forth such conceptions. Given this cause of faulting, the heretofore puzzling facts are satisfactorily and easily explained. Compression and tension still remain true causes of faulting, but mainly as local and proximate ones. The common expression, *tilting* of fault blocks, attains a deeper significance, for this tilting may be more largely the result of subcrust migrations than of the mere force of gravity. Cases of horizontal motion and pivotal motion become simple, for there is no necessary unchangeable relation between the direction of the force and the position of the fracture plane. The force may act parallel to, or at any angle less than 90° with, the plane of motion, producing a horizontal component of the differential motion of the crust blocks. If the force act below the centers of inertia of the crust blocks, which is a probable condition, pivotal faulting will result. Other possibilities are too evident to require further notice. The peculiar fact that very frequently the force producing differential motion of crust blocks acts at some large angle with the horizontal can be best explained on the assumption of subcrust migrations. One is thus led naturally to the consideration of the greater subject of crustal movements in general, concerning which there is such diversity of belief.

The force or forces producing faulting do two distinct kinds of work. The first of these is that of fracturing the crust, and the second that of actual dislocation. Given the direction of the force and a homogeneous material, we can, as a problem in physics, locate the possible fault planes. Given the direction of

[1] J. E. Spurr, "Geology of the Tonopah Mining District, Nevada," Prof. Paper No. 42, U. S. G. S., p. 80 et seq.

the force and, as is actually the case, a heterogeneous material such as the rocks of the earth's exterior, we cannot tell in what position the planes of fracture and motion will lie. The rocks break under stress along the planes of least resistance for a certain force, and not along the ideal planes that will develop by crushing a small cube of granite or other homogeneous material. To reverse these statements, in order to make them applicable to our needs, it can be stated that were the crust homogeneous, from given fault planes we could identify the direction of the force, under actual conditions we can seldom locate the direction of the force. We have taken as the natural plane a horizontal one in studying faults; as a matter of fact the horizontal plane is only remotely connected with the cause of faulting; its adoption as a datum is highly arbitrary, and has been a prolific source of the confusion on the subject. The second part of the work of the forces, that of dislocation, needs a little examination here. A force may vary continually in direction, due to the actual migration of material below, and thereby produce a variety of movements along the fracture planes. All the various types of faults are easily produced, the horizontal, the pivotal, the so-called igneous thrust, and the other commoner ones. And the production of normal and reverse faults depends both upon the direction of the force and the planes of easy fracture in the rock. Therefore it is evident for several reasons that normal and reverse faults can exist together, of the same age, and magnitude. It is easily possible to illustrate all cases of the various kinds of faults upon the basis of subcrust migration, but in this short paper it would be out of place. However, the few figures given illustrate some of the most important points. There is one further remark it seems desirable to make in this place regarding the question of faults. The term "gravity fault" is very frequently used synonymously with "normal fault." A little thought will show the error of this, for gravity by itself can produce faults only when the other much more intense forces become temporarily or permanently zero. A force or forces great enough to fracture the crust

will in nearly all cases, not necessarily in all conceivable ones, continue in operation after this first work has been done and will produce differential movement of the crust blocks formed. And since such force or forces are relatively great compared with gravity, except when the crust blocks are very large, it is not correct to consider gravity a fault producing force of the first magnitude. This fact has been recognized by some geologists without a formal statement. There is one reservation to be made to this, however: it may be that gravity is one of the ultimate and not yet understood causes of faults.

In view of all the above, the classification ond nomenclature of faults assumes a more serious aspect than could be desired. The recognition of the fact that faulting is of three dimensions instead of two complicates matters somewhat, as do the traces of genetic relations already showing in our present usage. We must henceforth work with caution, for the adoption of terms of negative value is to be scrupulously avoided. The writer has the following to offer. In studying a fault there are three things to be determined: (1) apparent motion; (2) real motion; (3) cause. This requires both a temporary and a final classification. It also indicates the nature of the most natural classification. First, the apparent motion ascertained, the fault can be given a temporary name, as, an apparently normal fault. Second, the true motion determined, the final name based upon form can be given, as, a horizontal fault with motion in (a certain) direction. And lastly, the cause determined, if possible, the form name is modified by adding to it the cause, as, a horizontal fault, with motion in (a certain) direction, caused by an igneous thrust. The important considerations regarding this mode are as follows:

1. The terms normal, reverse, and thrust, are at present intrinsically valueless. Yet it is very doubtful if we can now ever eliminate them, desirable as this may be. Hence, it seems best to use the term normal to cover those faults in which, using the horizontal plane as datum, the hanging wall has dropped relative to the foot, reverse to cover the reverse of

normal, and thrust to cover the cases of actual demonstrable thrust of the hanging wall over the foot. The two latter terms should not be used synonymously, for a reverse fault is not necessarily a thrust.

2. From the nature of faulting and the immediate needs of the geologist, the form of a fault is of more importance than the cause, hence the chief element for classifications should be the form.

3. Since the actual direction of the stress preceding faulting may be in any direction, we are forced to adopt an arbitrary datum plane. For obvious reasons this must be the horizontal plane. Then, for the sake of simplicity, normal and reverse faults should be such, irrespective of any horizontal element of motion. In case the movement were entirely or nearly horizontal, the fault should be classified as a horizontal fault, with motion in (a certain) direction.

4. There are certain terms, as pivotal, which should be used with caution, and in their narrow senses. A little consideration of the phenomena of faulting makes it evident that the varying friction in a plane of movement renders it certain that many, if not a great majority, of the faults are characterized by a motion of rotation as well as of translation, hence are pivotal. It is only when the rotation is large compared with the other motion that the term is well applied.

It appears to the writer that at this immediate time it is unwise to attempt a more formal discussion of faults, or go further into a complete scheme of classification. The attention of geologists must be called to the necessity of more complete observation and analysis of faults, in order that all facts pertinent to the subject may be ascertained and coördinated. When this is done the time will ripe for some one to present the complete and unified subject.

JOHN A. REID.

STOCKTON, CALIFORNIA.

ABSENCE OF LEAD AND COPPER FROM CERTAIN DEEP SEA DEPOSITS.

Sir:—While collecting fish for the Field Museum of Natural History, Dr. Tarleton H. Bean, in October, 1905, dredged from the Challenger and Argus Banks a large number of calcareous nodules, which have since been fully described in the publications of that Museum.[1]

The Challenger Bank whence most of the specimens came is a shoal of from five to ten miles diameter, rising abruptly from the depths of the sea to within twenty-four to thirty fathoms of the surface. The Bank lies thirteen miles southwest of Gibb's Lighthouse, Bermuda, and is separated from the Bermuda Bank by a space of three and one half miles of deep sea, where soundings exceeding 1,000 fathoms have been taken. The Argus Bank is a shoal of similar dimensions and depth of water about twelve miles southwest of the Challenger Bank from which it is separated by a trough of five hundred fathoms depth. There is no shallow water connection between these two banks nor with any other shoals or land.

The nodules found on these banks were first described by Sir Wyville Thompson as "large rounded pebbles of the substance of the Bermuda serpuline reef." They vary in length from about 2¾ to 6 inches and in thickness from about 2¼ to 4½ inches. They are composed exclusively of remains of calcareous organisms and are of concretionary origin.

As these nodules occur on a small isolated bank in mid-Atlantic, away from any possibility of impregnation or contamination by waters flowing from preëxisting mineral veins, the presence or absence of minute quantities of the heavy metals becomes a question of importance as it bears directly on the problem of the origin of ore deposits by lateral secretion and by ascension. The isolation of the material removes wholly the serious doubt present in most determinations of this character

[1] "New Forms of Concretions," H. W. Nichols, Field Columbian Museum, Pub. 111.

as to whether the metals found may not have originated in mineral veins and later impregnated the neighboring rocks. Hence, a search for traces of copper and lead was undertaken and carried out with great care.

Thirty-seven grams of the material were ignited and dissolved in dilute hydrochloric acid. The solution was filtered and the filter-paper burned. Its ash was fused with acid potassium sulphate and the fusion, dissolved in dilute sulphuric acid, added to the solution of the nodule. To this solution a quantity of sulphuric acid, calculated to be slightly in excess of that required to convert the whole of the bases to sulphates, was added. The precipitate was allowed to settle over night and was then filtered into a large filter. The precipitate was very thoroughly washed with a large volume of water which was added to the filtrate and the washed calcium sulphate rejected. The solution was then allowed to evaporate slowly until as large a quantity of calcium sulphate as could conveniently be filtered had separated. This was filtered and washed with a large quantity of water and rejected. The solution, with the wash water added, was again evaporated and the whole sequence of operations repeated again and again until solids began to separate from the solution only when it was reduced to a volume of 50 c.c. The acidity was then sufficiently reduced with ammonia and the volume made up to 150 c.c. with water.

The solution was heated to boiling and hydrogen sulphide passed through for two hours. The liquid which had been yellowish, became perfectly colorless and no visible precipitate of any kind appeared even after long standing. The quantity of lead that will produce a noticeable darkening of 150 c.c. of solvent under these conditions is excessively minute. The same is true of copper. The apparently perfectly clean filter, through which the solution had been passed, was disintegrated in aqua-regia which was added to the solution after the hydrogen sulphide had been removed by evaporation. The iron was then precipitated three times and the liquid evaporated until it became muddy. The ammoniacal liquor did not present the slightest blue tinge. The solution was diluted to 150 c.c. and allowed

to stand until it became clear, when it was saturated with hydrogen sulphide. The usual darkening of the liquid occurred but no visible precipitate. The liquid was filtered and the discolored paper tested for zinc with cobalt nitrate before the blowpipe with negative results. There is, therefore, no considerable quantity of zinc present and in all probability none. The writer has, however, little confidence in the reliability of any known tests for the detection of excessively minute quantities of zinc. Blanks were run to test the Baker and Adamson chemicals used but were discontinued when the negative results of the assay became apparent.

It is evident from these determinations that the limestones now forming on the Challenger Bank contain no traces of lead, zinc or copper and from these limestones at some future time no ore deposits can form by concentration. Whether the same is true for material from a sargasso sea remains to be determined when such material becomes available for study. The bottom of the Challenger Bank is covered with living animal and vegetable forms in such quantity, however, that it would seem that any effects of decaying organic matter ought to be evident there.

HENRY W. NICHOLS.

THE GEOLOGY OF THE GRANBY AREA.

DISCUSSION OF REVIEW BY C. K. LEITH.

Sir:—Permit me to call attention to several statements made by Dr. C. K. Leith in a review, in ECONOMIC GEOLOGY, No. 8, Vol. I., of the report on "The Geology of Granby Area" issued by the Missouri Bureau of Geology and Mines in 1905, Dr. Leith says: "It is argued that the waters could not come from below because faults are not as important as previously thought to be, though both faults and joints are present. Further evidence is needed to show that there may not still be sufficient fracturing to afford channels of escape for deep flowing waters." Our investigations have not been confined to the Granby Area but have covered most of the southwestern Mis-

souri or Joplin district. The authors of the Granby report, as well as those of the U. S. Geological Survey who have since done work in the district, have not announced the discovery of faults of sufficient magnitude to penetrate the Cambro-Ordovician. There are very few instances where the shape of the ore bodies or their distribution might lead one to infer the presence of such faults, and so far as known they do not exist. "Further evidence" is needed to show that they *are* present, not to show that they are "not" present. The burden of proof is upon him who believes in their presence or requires their presence for the explanation of his theory.

Leith says "the argument that the mine waters fluctuate with the seasonal precipitation does not necessarily show that part of the waters may not come from the artesian circulation." It may be recalled that Bain, in his report on the "Lead and Zinc Deposits of the Ozark Region" says that the mine waters do not fluctuate with the seasons and in arguing in favor of an artesian circulation offers this as one of the most important proofs. All information which we have gathered shows that the mine waters do fluctuate with the seasons and some of the wet mines become almost if not quite dry during dry seasons. Observations which we have made go to show that many of the wettest mines lose from 50 to 75 per cent. of their water during the dry seasons.

The reference which Dr. Leith makes to chemical sediments during the Cambro-Ordovician and mechanical sediments during the Pennsylvanian does not take into consideration the important factor of whether or not the Pennsylvanian water supplied the necessary reducing conditions, under which the metallic salts might be deposited from the sea water. To the authors it appears very clear that reducing conditions must have been more generally present in the shallow, estuarine sea conditions of the Pennsylvanian, through the decomposition of an abundant vegitation, than in the Cambro-Ordovician sea in which marine animal life was the chief source of organic decomposition.

The argument that the ores "should be found abundantly near the surface in parts of the Pennsylvanian only partly eroded,"

provided they were derived from the Pennsylvanian, is easily answered. Their absence in a concentrated form at this horizon is due, first, to the absence of abundant *openings,* at least in the shale, in which the lead and zinc minerals might be concentrated. Wherever openings occur, as in the coal pockets and in the geodes in the limestones lead and zinc ores occur in a concentrated form. Second, the surface waters bearing lead and zinc in solution entered the shallow Pennsylvanian sea only at widely separated points. The entire tributary region of older rocks, during Pennsylvanian times, may have been covered with not to exceed four or five drainage systems. Further, the lead and zinc salts in the streams emptying into the Pennsylvanian probably did not travel far from the shore, before being deposited in minute quantities through the carbonaceous sediments which were being laid down. Also some of the streams emptying into the Pennsylvanian sea may have collected their waters from areas in which there was little or no lead or zinc in the rocks.

As to whether or not the waters are acid or alkaline, no evidence has been published by those supporting the artesian theory. In the Granby report evidence, in the shape of analyses, was given in support of the contention that the mine waters contain acid sulphates. Wherever oxidation of the pyritous minerals is taking place the waters are acid. This is especially true in the case of waters in the Pennsylvanian strata, as shown by analyses such as are exhibited in a recent report of the Franklin Institute. Under the acid condition of the water the zinc salts would certainly be held in solution.

Dr. Leith concludes by saying that, "aside from the conclusion as to the source of the ores, the differences between the conclusions of Buckley and Buehler and those of Van Hise and Bain are not as fundamental as would be indicated by the emphasis on contrasting terms 'upward concentration' and 'downward concentration.'" This may be true, but, at the same time, it must be borne in mind that the differences in conclusions as to the source of the ore are *fundamental,* and that the other points, in which we do not differ fundamentally, are of secondary importance.

We believe with Van Hise and Bain, that the lead and zinc was at one time disseminated in part at least, through the Cambro-Ordovician. We differ from them in believing that the lead and zinc salts were transferred directly from the Cambro-Ordovician to the Mississippian. It is our belief that they were transferred from the Cambro-Ordovician rocks to the Carboniferous ocean and deposited with the sediments of that time.

Without this intermediate step in the transference of the lead and zinc salts the theory of a concentration in the Mississippian by a process of continuous downward circulation would not be tenable. On the other hand, the transference of the material from the Cambro-Ordovician directly to the Mississippian requires the theory of an artesian circulation.

According to their own published statements the theory of Van Hise and Bain requires certain structural conditions which no one has shown to exist in the district.

Provided we had not studied the District outside of the Granby Area, and provided our conclusions were based entirely on an examination of the Granby Area (which is not the case), even then it does not seem reasonable to suppose that one theory of origin could be applicable to this part of the district while another theory is applicable to the remainder. Attention might be called to the work of the Lake Superior geologists where the application of a single theory of the origin of the iron ore has been made in districts that are widely separated geographically. Is it not as reasonable to suppose that the origin of the lead and zinc ores of southwestern Missouri has been essentially the same in all parts of the district?

E. R. BUCKLEY.

ROLLA, MO., February 1, 1907.

REVIEWS

Report on the Geology of Graham Island. By R. W. Ells. Geological Survey of Canada. Ann. Rep. Part B, Vol. XVI., 1906, pp. 46, 2 maps.

Graham Island is the most northerly and largest of the Queen Charlotte group, situated off the west coast of British Columbia. To the north across Dixons Entrance, a distance of 35 miles, is the boundary line of southeast Alaska.

The recent discoveries and development of extensive coal fields in the central portion of this island, also the quarrying of slate deposits on the south shore, and the occurrence of auriferous beach sands along the east coast, these latter of minor importance, makes this island of much commercial interest.

The investigations forming the basis of the present report were to ascertain if possible something definite as to the geology and structure of this new coal field. Before attacking the problem in detail Mr. Ells made a reconnoissance of the shore line around the entire island, and with this general knowledge he then went inland to study the coal-bearing rocks in detail.

In his report mention is made of the investigations of the Queen Charlotte Islands by Dr. G. M. Dawson in 1878,[1] also of the timber explorations in 1885 by Mr. W. A. Robertson who first discovered the presence of coal in the streams tributary to the Takoma river and found the valuable deposits known as the Wilson and Robertson seams.

Considerable space is given to descriptions of the inlets, harbors and hydrographic notes all of which are valuable to anyone planning to navigate in this section. Observations of zoölogical and botanical interest are also included, and a few paragraphs devoted to the natives who inhabit the islands.

[1] Report of Progress for 1878–79, Geol. Survey of Canada, 1880, pp. 1B–239B.

Both physiographically and geologically Graham Island may be divided by a line drawn through Masset Inlet on the north end to Skidegate harbor on the south. The west half of the island is rugged with mountain peaks rising from 2000 to 5000 feet in altitude, many of them cone shaped and snow covered, and made up of igneous rocks. To the east the land sculpture is relatively low and flat and is composed of sedimentaries.

The rock formations exposed on the island are classed under four heads: Post-tertiary, Tertiary, Cretaceous, and Igneous rocks comprising Pre-cretaceous and later Tertiary.

The Post-tertiary beds include sands, gravels and clays. Deposits of the latter are wide-spread, usually underlying the sand beds and frequently contain marine shells and lignite fragments. The sands and gravels are prominent along the northeast shore forming dunes and ridges caused by storms frequent along the coast. Near tide-water thin layers of auriferous black sands have been found and located for mining purposes. The bed-rock source of this gold is unknown.

The Tertiary formation embraces both sedimentary rocks, sandstones, shales and conglomerates with occasional beds of lignite, and volcanics, which cover the northwest portion of the island and overlie the sedimentaries. These sediments which are confined to the eastern half of the island show much false bedding and irregularity of deposition. Interstratified in them the coal or lignite seams are small and of little economical value.

The Cretaceous or coal bearing rocks of the island comprise a considerable thickness of shale sandstone and conglomerate with thin limestone bands. They are exposed along the south shore of the island and extend northward along the eastern flank of the mountain range composed of pre-existing igneous rocks. To the east they are limited by the overlying Tertiary beds.

The structure of these beds was found to be quite simple and may be defined by two rather flat anticlines and a syncline striking in a northerly direction. A detailed description is given of the section along the south shore of the island and of

many points of exposure up the creeks and along the trail to the Robertson and Wilson coal seams.

At Camp Robertson, situated 8 miles from Skidegate Harbor, and 900 feet above sea-level, several outcrops of coal occur, interstratified in the upper cretaceous sandstones and shales. Both the coal and enclosing beds are much broken and dip at steep angles, sharp anticlines were observed and occasional intrusive dikes. These disturbances have faulted the coal seams in places and will affect mining materially. Several openings consisting of shafts and tunnels have been made along these seams exposing an upper bed 8 feet thick and a lower bed 12 feet thick over a length of 300 feet. In both of these shale partings occur and the coal is often badly crushed.

Wilson Camp lies 9 miles to the north or 17 miles by trail from Skidegate Inlet and 200 feet above sea-level. At this point the bed rocks are less disturbed, though the coal seam itself is locally faulted. The thickness of the Wilson seam is 17½ feet with a 6 by 12 inch parting of sandstone near the base. The strike is to the northwest and dip steep to the northeast. The present developments which consist of a short tunnel and shaft are not sufficient to determine its value as a future coal producer.

In conclusion Mr. Ells states that a vast area of coal exists at both Wilson and Robertson camps, and should be investigated by borings. He also points out the most favorable localities to attempt such investigations and discusses the matter of shipping facilities. A number of analyses of the coals are added and the relative value of the coal stated.

The last page of the report is devoted to the igneous rocks occurring on the western half of the island. These are divisible into two classes, viz., those of Pre-cretaceous and those of the later Tertiary. The former, occupying the southwestern portion, comprise areas of diabase, felsitic and porphyritic rocks, agglomerates, etc., with an occasional bed of altered limestone. These igneous rocks underlie the Cretaceous rocks and are penetrated by various dike rock and huge masses of granite. Traces of copper have been observed locally but nothing of importance has

been found. The later Tertiary volcanics were observed to rest upon the Tertiary sedimentaries. They comprise a series of basaltic lavas, the bedding of which is practically undisturbed by folding or faulting. No minerals economically important were seen in these rocks. Accompanying the report are two geological maps, a general geological map of the island and one in detail showing the position of the two mining camps.

The report as a whole is of much value for the purpose intended and a worthy contribution to the geology of the Pacific coast. There is, however, a noticeable lack of notes on the petrography and relations of the igneous rocks and a careful study of these would no doubt bring out facts of utmost importance to geologists who have worked along this coast and had similar problems to contend with.

CHARLES W. WRIGHT.

The Peabody Atlas. Coal Mines and Coal Railroads. By A. BEMENT. Published by the Peabody Coal Co., Chicago.

This atlas, consisting as it does of 150 pages of carefully prepared text and including 25 colored maps, is an interesting example of the breadth of view characterizing modern business methods. It is published primarily to stimulate the use of coals from the central commercial district of the United States, within which the Peabody Company has many mines. The price placed on the atlas, $5.00, is merely to permit its handling in the regular trade and not with a view to producing a direct return for the money invested.

The essential portion of the atlas is a series of maps accompanied by suitable explanatory lists, showing the location of the shipping coal mines of Ohio, Michigan, Indiana, Western Kentucky, Illinois, Iowa and Missouri. These are fields which furnish the bulk of the coal sold in the competitve markets of the middle west. The maps will be exceedingly useful to every one interested in the coal industry. Such maps never can be entirely accurate since changes occur faster than the printer works. In the present atlas mistakes are perhaps not more numerous than is inevitable, though such omissions as that of all the mines along

the C. M. & St. P. Ry. in Appanoose County, Iowa, strikes one as unfortunate.

Preceding the detailed maps are two showing the coal fields of the United States and the relative intensity of production in the different areas. There are also brief descriptive notes on the geology of the various coal fields and the correlation of the most important coal seams. With these are partial analyses showing the ash and moisture content and relative heating power of various assumed average coals from each field. These are interesting as expressing the opinion of an engineer of wide practice as to what constitutes the average coal in each case. They are not known to have been mathematically derived or to be based on uniform and widespread sampling, and must accordingly be taken as expressing a personal opinion only. Apparently the analyses represent the coal in the market and not at the mine.

Following the maps is a brief but well illustrated text on smokeless furnaces for burning such coals as occur in this territory. It is to be hoped that the information there given may be widely disseminated as it is founded on actual practice and is of proven value.

H. F. BAIN.

RECENT LITERATURE ON ECONOMIC GEOLOGY.

COMPILED BY

G. F. LOUGHLIN, F. H. MOFFIT AND J. T. SINGEWALD.

METALLIFEROUS DEPOSITS.

CHROMITE.

Chromitvorkommen von Neudorf und Asplenium Serpentini. By A. MAKOWSKY. Verh. d. nat. Ver. in Brünn. XLIV., 1905 (Brünn, 1906). Sitz.-Ber. Pp. 35.

COPPER.

Bemerkungen zur Arbeit "Zur Kenntnis der Kieslagerstätten zwischen Klingental und Graslitz im westlichen Erzgebirge" von Dr. Otto Mann in Dresden. By B. BAUMGÄRTEL. Zeit. f. Prakt. Geol., 14, 1906, Heft 5. Pp. 150–151. (Abstract in Geol. Centralbl., IX., 1, p. 9, 1907.)

Copper Mines of Collahuasi, Chile. By J. MURO. Bull. Internat. Bureau of American Republics. Dec., 1906.

Copper Mining at Bisbee, Arizona. By ROBERT B. BRINSMADE. Mines and Minerals. Vol. XXVII., No. 7, Feb., 1907. Pp. 289–293.

The Copper of Shasta County, California. By DONALD F. CAMPBELL. Mining and Scientific Press. Vol. XCIV., No. 1, Jan. 5, 1907. Pp. 28–30, and No. 2, Jan. 12, 1907, pp. 55–58.

Die Fahlerz- und Quecksilbererzlagerstätten Bosniens und der Herzegowina. By F. KATZER. Berg. u. Hm. Jahr. d. Hochschulen zu Leoben u. Pribram. 55 Bd., 1902. Pp. 121, with 25 figures and one plate. Vienna: Manz, 1907.

Les Gisements de Cuivre de la Regio de Ferrol, Province de Corogne (Espagne). L'Echo des Mines. Jan. 31, 1907.

The Katanga Copper Field. Correspondence in the Mining Jour. Vol. LXXXI., Jan. 5, 1907. Pp. 14.

Zur Kenntnis der Kieslagerstätten zwischen Klingental und Graslitz im westlichen Erzgebirge. By O. MANN. S.-Ber. u. Abh. d. Nat. Ges. Isis in Dresden, Jg. 1905, Abh. Pp. 86–99.

Das Kiesvorkommen am Laitenkofel pb Rangersdorf im Mölltale. By R. CANAVAL. Jahrb. d. Naturw. Hist. Museums von Kärnten 17 Heft. Pp. 417–423.

Map of the Bonmahon Copper Fields (Ireland). With Geological Section. Copyright edition. By H. T. MARKS, M.I.M.E., and B. W. COURTNEY, A.R.S.M. 21s. London: Effingham Wilson.

La region cuprifera de los abredores de Ica y Nasca. By G. F. FUCHS. Bol. del cuerpo de ing. de minas del Peru. Nr. 29, 1905. Pp. 100, with one plate and one map.

The Lost Packer Copper Lode. By E. P. JENNINGS. Journal of the Canadian Mining Institute. Vol. IX., 1906. Pp. 44–57.

Region cuprifera de Cachi-cachi. Province de Tarma y Jauja. By A. COLONGE. Boletin de Minas, Industria y Construcciones. Publicado por la Escuala especial de Igenieros. Serie II., Tome I., Num. IV.

Some Observations Relative to the Occurrence of Deposits of Copper Ore on Vancouver Island and other portions of the Pacific Coast. By W. M. BREWER. Journal of the Canadian Mining Institute. Vol. IX., 1906. Pp. 39–48.

GOLD.

Ancient Workings in the Northern Transvaal. By J. M. CALDERWOOD. So. Afr. Mines. Dec. 29, 1906. 1 p.

The First Gold Discoveries in New Zealand. By R. A. LOUGHNAN. New Zealand Mines Record. Vol. X., pp. 1–9, 43–52, 87–102, 1906. (Concluded from page 503, Vol. IX.)

The Gold Mining Districts of Central Siberia. By L. B. BROWN. The Mining Journal. Vol. LXXXI., Feb. 9, 1907. Pp. 182–183. (Abstract of a paper read before the American Inst. of Min. Eng.) (To be continued.)

Gold Mining in West Africa. By W. FISCHER WILKINSON. Engineering and Mining Journal. Vol. 83, No. 4, Jan. 26, 1907. Pp. 182–183.

Ein Goldvorkommen bei Netting in der Neuen Welt nächst Wiener-Neustadt und seine morphologische Bedeutung. By R. SCHOBER. D. Rundschau f. Geogr. u. Statistik, 27, 1905. Pp. 529–541, with five text-figures. (Abstract in Geol. Centrlbl., IX., 1, p. 6, 1907.)

Metasomatic Process in the Gold Deposits of Western Australia. By W. LINDGREN. The Mining Journal. Vol. LXXXI., Feb. 2, p. 148; Feb. 9, p. 183, 1907.

Mines of the Transvaal. By R. R. MABSON. Fourth edition (1906–7). Pp. 776, with maps and plans. 5 x 8 in.; cloth, $6. London, 1906. "The Statist."

The Mount Lyell Mining Field, Tasmania, with some account of the Geology of Other Pyritic Ore Bodies. By J. W. GREGORY, D.Sc., F.R.S., Professor of Geology in the University of Melbourne, and Director of the Geological Survey of Victoria. Price 7s. 6d. The Mining Journal, 46 Queen Victoria Street, London, E. C.

On the Occurrence of Gold in Finnish Lapland. By C. FIRCHS. Bull. Comm. Géol. de Finlande No. 17. Helsingfors, 1906. Pp. 35, with 15 figures, one plate, and one map (i. M.). 1 : 100,000.

Les Richesses minérales de la Serbie.—I. Les gisements aurifères. By IOVANOVITCH, geologue. In 4°, with 56 figures and one map. H. Dunod and E. Pinat, éditors, 49 quai des Grands-Augustins. Paris, VI°. Price 10 francs.

Round Mountain Camp, Nevada. By GEORGE A. PACKARD. Engineering and Mining Journal. Vol. 83, No. 3, Jan. 19, 1907. Pp. 150–151.

Second Report Oaks View Gold Mines (near Rockhampton), and Notes on the Mines Talgai and Thane's Creek Goldfields. By L. C. BALL. Geol. Surv. of Queensland, Pub. No. 205. 36 pp., three plans, and two plates.

The Starcke, Alice River (Philip), Hamilton, and Coen Goldfields of the Cape York Peninsula. By W. E. CAMERON. Queensland Govt. Mg. Jour., Dec. 15, 1906. 5 pp.

Uber die weite Verbreitung des Goldes. By A. RICHTER. Nat. Woch., 21 (= N. Folge 5), 1906. Pp. 729–730.

IRON.

Die Bedeutung der Siegerländer Eisenerzvorkommen für die Versorgung der deutschen Eisenindustrie. (Statistik für 1895 bis 1905—Vorratsschätzung.) By W. VENATOR. Stahl und Eisen, 1907. Pp. 127–131.

Die Brauneisensteinlagerstätten des Seen- und Ohmtals am Nordraude des Vogelsgebirges. By H. MÜNSTER. Inaug.-Diss. Giessen, 1906. Pp. 21.

New Sources of Ore Supply in Alabama. By THOMAS P. GRASTY. Manufacturers Record. Vol. 21, No. 4, Feb. 7, 1907. Pp. 91–92.

LEAD.

Verkommen, Gewinnung, und Aufbereitung des Blei- und Kupfererze des Pinar de Bédar in Süd-Spanien. By O. PUTZ. Zeit. für das Berg-Hütten- u. Salinen-Wesen. Band 54, 5. Heft. Pp. 675–683, 1906.

Development in the Coeur D'Alenes. Lead and Zinc News. Vol. XII., No. 10, Jan. 14, 1907. Pp. 5–7.

Structural Relations of the Wisconsin Zinc and Lead Deposits. By ULYSSES SHERMAN GRANT. Lead and Zinc News. Vol. XII., No. 11, Jan. 28, 1907. Pp. 5–7.

Ore Deposits of the Joplin District. By F. L. CLERC. Proceedings of the Colorado Scientific Society. Vol. VIII. Pp. 199–220. Denver, 1906.

MERCURY.

Die Fahlerz- und Quecksilbererzlagerstätten Bosniens und Herzegowina. By F. KATZER. Berg. u. Hrn. Jahr. d. Hochschulen zu Leoben u. Pribram. 55 Bd., 1902. Pp. 121, with 25 figures and one plate. Vienna: Mauz. 1907.

Quicksilver in California. By CHARLES G. YALE. Mining and Scientific Press. Vol. XCIV., No. 1, Jan. 5, 1907. Pp. 22.

Zinnoberkristalle aus Sonoma County in Kalifornien, Gips und Kalkspatkristalle von Terlingua in Texas. By A. SACHS. Centralbl. f. Min. Geol. u. Pal. 1907, No. 1. Pp. 17–19.

NICKEL.

The Atik-okan Nickeliferous Pyrrhotite Deposits and their Origin. By F. HILLE. Journal of the Canadian Mining Institute. Vol. IX., 1906. Pp. 285–302.

Genetic Relations of Nickel-Copper Deposits. By C. W. DICKSON. Journal of the Canadian Mining Institute. Vol. IX., 1906. Pp. 236–260.

Los yacimientos de niquel de Rapi. By E. A. V. DE HABICK. Bol. Cuerpo Ingen. de Minas del Peru. No. 11. Pp. 1–30; 8° with one plate. Lima, 1904. (Abstract in Geol. Centralbl., Bd. IX., No. 1, p. 7, 1907.)

Notes on a Deposit of Nickeliferous Pyrrhotite at Malachite Point. By ARMAND MUSCOVICI. Journal of the Canadian Mining Institute. Vol. IX., 1906. Pp. 221–222.

On the Nickel Deposits of Webster, Western North Carolina. By ALFRED E. BARLOW. Journal of the Canadian Mining Institute. Vol. IX., 1906. Pp. 303–316.

The Ore Deposits and Geology of the Sudbury District. By HIRAM W. HIXON. Journal of the Canadian Mining Institute. Vol. IX., 1906. Pp. 223–225.

PLATINUM.

Explotacion del platino. Boletin de la Secretaria de Fomento (Mexico). Año VI. Diciembre de 1906. Num. 5, p. 372.

The Occurrence of Platinum. (From Bull. Imp. Inst.) Can. Mg. Rev. Vol. XXVIII., No. 1. Pp. 8–10, 1907.

The Production of Platinum. By F. W. HORTON. (From Advance Sheets, Min. Res. U. S.) Can. Mg. Rev. Vol. XXVIII., No. 1. Pp. 12–13, 1907.

SILVER.

Cobalt, Ontario (illustrated and map). By T. A. RICKARD. Mining and Scientific Press. Vol. XCIV., No. 1, Jan. 5, 1907. Pp. 23–25.

Mining in Eastern Canada. PROFESSOR PARKS on Cobalt Correspondence in The Mining Journal. Vol. LXXXI., Jan. 12, 1907. Pp. 43.

The Mines of Cobalt (illustrated). By REGINALD MEEKS. Engineering and Mining Journal. Vol. 83, No. 3, Jan. 19, 1907. Pp. 138–141; No. 4, Jan. 26, 1907. Pp. 186–188; and No. 6, Feb. 9, 1907. Pp. 274–276.

Note on Windy Arm Silver Bearing Veins. By R. G. MCCONNELL. Journal of the Canadian Mining Institute. Vol. IX., 1906. Pp. 49–53.

TIN.

The Annan River Tinfield (concluded). By W. E. CAMERON. Queensland Gov't Mg. Jour., Nov. 15, 1906. 7 pp.

Cornish Tin Mining. By H. E. WEST. Mining and Scientific Press. Vol. XCIV., No. 6, Feb. 9, 1907. Pp. 179–181, and No. 7, Feb. 16, 1907. Pp. 213–214.

Report on Cox's Bight Tin-Field. By W. H. TWELVETREES. Pamphlet of the Govt. Geologist. Tasmania, 1906. Pp. 18 with map.

Tinstone in Canada. Can. Mg. Rev. Vol. XXVIII., No. 2. Pp. 39–40, 1907.

TUNGSTEN.

Informe sobre los yacimientos de tungsteno de la Provincia de Angaraes. By E. A. V. DE HABICH. Bol Cuerpo Ingen. de Minas del Peru, No. 11. Pp. 31–39; 8°, with one plate. Lima, 1904. (Abstract in Geol. Centralbl., IX., 1, p. 9, 1907.)

NON-METALLIC DEPOSITS.

AMBER.

Gisements du succin de Roumanie avec un aperçu sur les résines-fossiles: succinite, romanite, schraufite, simétite, birmite, etc., et un nouvelle résine-fossile d'Olanesti. By G. MURGOCI. Extr. de "Asoc. Romana pentru in aintarea si reppandirea sciintelor, Mem. Congr. de la Jasi." Bucarest, 1903. Pp. 34 with 14 figures and one map.

ASPHALT.

El Asfalto y sus aplicaciones. By E. COLLAND. La Ingenieria. Nov. 30, 1906.

Les Calcaires Asphaltiques du Gard. By M. P. NICOU. Ingénieur au Corps des Mines. Annales des Mines. Tome X., 11, Livr., 1906. Pp. 513–568, with 16 figures in the text. I. Usages de l'asphalte, p. 514; II. Esquisse géologique de la région asphaltique du Gard, p. 517; III. Historique de l'asphalte dans le Gard; IV. Etude des différentes concessions de calcaire asphaltique, p. 523; Recherches d'asphalte, p. 545; VI. Conclusion, p. 564; Annexe, Schistes bitumineux de bagnas.

CEMENT.

Cement for Sea-Water Construction. By S. B. NEWBERRY. Cement Age. Jan., 1907. 4 pp.

Cement Industry of the World. Compiled by R. W. LESLEY. Cement Age. Jan., 1907.

Ueber den Einfluss einiger Lösungen auf Portland- und Schlackenzement. By H. RENEZEDER. Oest. Wochenschrift für den öffentlichen Baudienst. Jan. 19, 1907. 3½ pp.

CLAY.

Die Enstehung der Kaolinerden der Gegend von Halle a. S. By E. WÜST. Zeit. f. Prakt. Geol. XV. Jahrgang, Heft. 1. Pp. 19–23, 1907.

Uber pyrometrische Untersuchung der Tone. B. ZSCHOKKE. Vortrag. Bern, 1904. 14 pp., 8°, and 7 tables. (Abstract in Geol. Centralbl., IX., 2, p. 60, 1907.)

Kaolin Mining in Georgia. By OTTO VEATCH. Engineering and Mining Journal. Vol. 83, No. 6, Feb. 9, 1907. Pp. 278–279.

Die untersuchten Tone der Länder der ungarischen Krone. By KALECSINSZKY. Translation of the Hungarian original appearing in March, 1905. (Vergl. d. Z., 1895, p. 216.) Publ. d. Kgl. Ungar. Geol. Anstalt, Budapest, 1906. Pp. 234, with sketch map, i. m. 1:900,000.

Wie wird bei Anlage eines Kalksandsteinwerkes die Herstellung guter Kalksandsteine gewährleistet? By W. DRAKEBUSH. Tonindustrie Zeitung. Jan. 10, 1907. 1 p.

COAL.

Le Bassin Houiller du Nord de la Belgique. Memoirs, notes and documents. **Supplement au Tableau Synoptique des Soudages de la Campine.** By L. DENOËL, Ingénieur principal des mines. Annales des Mines de Belgique. Tome XII., 1re Liv. Pp. 203–204, 1907. (See Tome IX., 1re Liv. Pp. 185, 1904.)

Beiträge zur Kenntnis der Lettenkohle und des Keupers in Schwaben. By F. ZELLER. Centralbl. f. Min., Geol. u. Pal. 1907, No. 1, pp. 19–29; No. 2, pp. 42–51.

Die Bekämpfung der Wassersand- (Schwimmsand-) Gefahr beim Braunkohlenbergbau. By H. NIESS. Pp. 104, with 19 sketches. 6½ x 10 in.; paper. Freiberg in Sachsen, 1907. Craz & Gerlach.

Our Coal. By F. Z. SCHELLENBERG. Paper read before Engineer's Society of Western Pennsylvania, Dec. 18, 1906. Vol. XXII. Pp. 481–493, Jan., 1907.

Das Braunkohlenvorkommen und der Betrieb der Grube "Cons. Preussen" bei Müncheberg in der Mark. By NOPPE. "Braunkohle." V., 1906. Pp. 555–559, with figures 218–222.

The Canobie coalfield, its geological structure and relations to the carboniferous rocks of the North of England and Central Scotland. By B. N. PEACH and J. HORNE. Trans. Roy. Soc. 1905. Pp. 43, with three plates and one colored map. Edinburgh.

Carbon de Piedra en el Estado de Coahuila. El Comercio. Jan. 15, 1907. **Deuxième partie de la seconde vue du bassin houiller du Pas-de-Calais, du Nord, et de la Belgique.** By L. BRETON. Soc. de l'Ind. min. Comptes Rendus Mens., 1907. Pp. 6–14, with plates I.–VI.

Coal Mining in China (illustrated). By NOAH FIELDS DRAKE. Mining World. Vol. XXVI., No. 7, Feb. 16, 1907. Pp. 240–242.

Zur Genesis der Minerakohlen und Relief der Kohlenformation von M. Ostrau. By A. MAKOWSKY. Verh. d. nat. Ver. in Brünn. XLIV., 1905. Brünn, 1906. Sitz.-Ber. Pp. 34.

Geological Survey of Glen Grey, and Parts of Queenstown and Wodehouse, including the Indwe Area. By A. L. DU TOIT. An. Rep. Geol. Comm., Cape of Good Hope, 1905. Cape Town, 1906. Pp. 95–140, with seven figures and one geologic map. The (coal producing) Indwe Area, p. 106; Bibliography, p. 140.

The Geology of the Transvaal Coal-Measures with special reference to the Witbank Coal Field. By E. T. MELLOR. Transvaal Mines Dept. Geological Survey. Memoir No. 3.

La houille au nord de Rouen. By LAUR. Comptes Rendus. Nov.–Dec., 1906. Pp. 333–373.

Mitteilungen aus dem Braunkohlenbergbau des Westerwaldes. By DORSTEWITZ. Braunkohle. V., 1907. Pp. 635–639.

Mitteilungen über Kohlenförderung und Kohlenhandel des In- und Auslandes. Beilage zu den "Nachr. f. Handel u. Industrie," Berlin, Reichsamt d. Innern. IV. Quartel, 1906. No. 114, 3 pp.; No. 122, 14 pp.; No. 127, 3 pp.; No. 134, 14 pp.; No. 137, 3 pp.; No. 142, 13 pp.

Montana Coal and Lignite Deposits (illustrated). By J. P. ROWE. Mining World. Vol. XXVI., No. 3, Jan. 19, 1907. Pp. 62–65.

Les plissements des morts-terrains comparées à ceux du terrain houiller. By LEMIÈRE. Comptes Rendus Mensuels. Feb., 1907. Pp. 69–75.

The Position of the Transvaal Coal-Measures in the Karroo Sequence. By E. T. MELLOR. Trans. Geol. Soc. of So. Africa. Vol. IX., 1906. Pp. 97–110.

Das Steinkohlengebirge an der Grenze von Oberschlesien und Mähren. By P. GEISENHEIMER. Breslau, 1906. Pp. 50. Price M. 1, 80; Berg- u. Hm. Rundschau, 1906. III. Pp. 1–8, 15–20, 29–35, with 8 profiles.

Der Steinkohlen Bergbau des preussischen Staats. im Saarreviere. Reisebericht. By F. OKORN. Berg- und Hüttenmännisches Jahrbuch. LV. Band, 1. Heft, 1907. Pp. 1–80, with plate I. Wien, 1907.

Manzsche k. u. k. Hof. Verlags- und Universitäts-Buchhandlung. I., Kohlmarkt 20.

Uber Steinkohlenformation und Rotliegendes bei Landeshut, Schatzlar, und Schwadowitz. By J. HERBING. Pp. 88, with figure and two plates. Breslau, 1906. Price M. 2.50.

DIAMOND.

De Beers Consolidated Diamond Mines. The Mining Journal. Vol. LXXXI. Jan. 12, 1907. Pp. 45–46.

Diamond Mining in the Orange River Colony (continued). South Africa Mines. Dec. 1, 1906.

GRAPHITE.

Graphite in Queensland, with Special Reference to the Mount Bopple Graphite Deposits. By B. DUNSTAN. Geol. Surv. of Queensland, Pub. No. 203. 20 pp., and 5 plates.

MICA.

Mica and the Mica Industry. By GEORGE WETMORE COLLES. Published by the Franklin Institute, Philadelphia. 1906. Pp. 130, with plates.

PETROLEUM.

Geologie der Petroleum-zone von Bustenari-Campina, Rumänien. By V. ARADI, JR. Ungar. Montan-Ind.- u. Handelsztg. 1907. XIII. Pp. 1–2.

Guide du sondeur au Pétrole. By V. PETIT. Géologie appliquée. Paris, 1905. With eight plates and fifteen figures.

Petroleo y carbon de piedra. POR J. DIEGO FERNANDEZ. Boletin de la Secretaria de Fomento, Mexico. Ano VI. Diciembre de 1906. Num. 5. Pp. 377–417.

Les pétroles dans l'Amerique du Sud. By FROCHOT. Soc. de l'Ind. Min. Comptes Rendus Mens. 1907. Pp. 37–53.

A Treatise on Petroleum. By SIR BOYERTON REDWOOD, D.Sc., F.R.S.E., Assoc.Inst.C.E., F.I.C. Second edition. Two volumes. 45s. London: Charles Griffin & Co., Limited.

Los yacimientos de petroleo del departamento de Piura. POR JUAN VALASQUEZ JIMENEZ. Boletin del Ministerio de Fomento. Año IV., N. 9. Setiembre de 1906. Pima-Peru. Pp. 83–123.

PHOSPHATES.

The Clarendon Rock Phosphate Deposit, near Milton, Otago. By A. ANDREW. New Zealand Mines Rec. Vol. X., No. 2. Pp. 52–57, 1906. (Abstract from Trans. Austral. Inst. Min. Eng., Vol. XI., 1906.)

PRECIOUS STONES.

Geologie des Nephrites im Südlichen Ligurien. By KALKOWSKY. Zeit. Geol. Ges. July, 1906. Pp. 307–378.

Mitteilung aus dem mineralogischen Institut der Universität Kiel. I. **Beiträge zur Kenntnis des Turmalins aus Brasilien.** By G. REIMANN. N. Jahrb. f. Min., Geol. u. Pal., XXIII. Beil.—Bd., Erstes Heft. Pp. 91–162, with plates IV.–VI.

Synthèse du quartz améthyst; recherches sur la teinture naturelle ou artificielle de quelques pierres precieuses sous les influences radioactives. By BERTHELOT. C. r. 143, 1906. Pp. 477–488.

RARE EARTHS.

Die Mineralien der südnorwegischen Granit-Pegmatitgänge. 1, Niobate, Tantalate, Titanate, und Titanoniobate. By W. C. BROGGER. Kristiania Selskabets Skrifter. Mat. Nat. Kl. 1906.

Das Pechblendevorkommen in Gilpin-County, Colorado. By W. TOVOTE. Osterr. Z. f. Berg. u. Hutt., 54, 1906. Pp. 223–224, with plate IV. and figures 9–11. (Abstract in Geol. Centralbl., IX., 2, p. 58, 1907.)

Radium and Geology. By O. FISHER, J. JOLY, and T. M. READE. Nature, 74. No. 1928, p. 585; No. 1930, p. 635. 1906.

Thorium Minerals. By S. FRY, Director Westport School of Mines. New Zealand Mines Record. Vol. X., No. 2. Pp. 62, 1906. (Abstract from Australian Mining Standard.)

Ueber Uranerze aus Deutsch-Ostafrika. By MARCHWALD. Centrlb. f. Min., Geol. u. Pal. 1906, No. 24. Pp. 761–763.

ALKALINE SALTS.

Ueber die Herkunft des Salzes im Meerwasser. By F. VON RICHTHOFEN. (Lecture.) Berlin, 1904. Naturwiss. Wochenschrift, 1907. Pp. 28–29.

L'industrie des sels de potasse. By E. BOENFOE. Travailleur Afrigain. Jan. 15, 1907. 1 p.

Uber Kainit von Stassfurt und Cornallit von Beienrode. By C. BUSZ. Sitzungsber. der Med. naturw. Gesellsch. zu Münster i. W. June 22, 1906. Pp. 5.

The Potash Industry. By GEORGE RYCE, B.A., A.E.C.S., F.C.S. The Mining Journal. Vol. LXXXI., Jan. 19, 1907. Pp. 86. (Abstract of the paper read before the Eng. and Sci. Assoc. of Ireland.)

"Das Salz" dessen Vorkommen und Verwertung in samtlichen Staaten der Erde. By J. O. F. VON BUSCHMANN, Ministerialrat im k. k. Finanzministerium zu Wein, herausgegeben mit Unterstützung der Kaiserl. Akademie der Wissenschaften in Wein. 2 Bände, Leipzig, Verlag von Wilhelm Engelmann. 1906. 18 M. (Abstract in Glückauf, 43. Jahrg. Nr. 8. Pp. 228–232, 1907.)

Untersuchungen über die Bildung der orcenischen Salzablagerungen, Auftreten von Polyhalit und Haugit bei 83°. By VAN'T HOFF and J. D'ANS. XLVII. Sitzungber. Berlin akad., 1906. Pp. 412–429, with two text-figures.

DESCRIPTIVE OF ORE DEPOSITS.

Bemerkungen über einige Erzvorkommen am Sudabhange der Gailthaler Alpen. By R. CANAVAL. Carinthea II. No. 3. 1906. 8 pp.

Economic Geology of the Beaver Quadrangle, Pennsylvania. By LESTER H. WOOLSEY. Bul. U. S. Geol. Survey No. 286. Deals with the coal, oil, gas, clay, etc., of the area.

Der Erzberg von Gellivare, Schweden. By A. DELLWIK. Jernkontorets Ann. 1906. Bd. 60. Pp. 259.

Die Gangverhältnisse des Siegerlandes. By BORNHARDT. Vortrag, geh. 6. June, 1906. V. d. Nat. Ver. d. Preuss, Rheinlande und Westfalens, 63, 1906. Hälfte 1. Pp. xliv.

Il giacimento di azzurite del Castello di Bouvei presso Mara (Sardegna) con alcune osservazioni sulle formazione dei carbonati di rame naturali. Rasegna Mineraria, Jan. 21, 1907. 2 pp.

Les gites metallifères du Val de Villé (Alsace). By UNGEMACH. Bull. Soc. Franc. de Minéralogie. 29, 1906. Pp. 194–283.

The Le Roi Mine—Its Past History and Present Condition. By E. JACOBS. (B. C. Mg. Rec., Nov., 1906. 9½ pp.)

Die nutzbaren Mineralien und Gebirgsarten im Deutschen Reiche. Auf Grundlage des gleichnamigen v. Deschenschen Werkes, unter Mitwirkung von H. Bücking neu bearbeitet. By W. BRUHNS. Berlin: G. Reimer, 1906. Pp. 859, with a geologic map of Germany i. M. 1:4,600,000. Price M. 16.

Die nutzbaren Mineralien und Gesteine der Merkgrafschaft Mähren und des Herzogtums Schlesien. By H. LAUS. Mit einer geologischen Ubersicht (samt Karte) und einem Verzeichnis der Hauptfundorte mährschles Mineralien. Brünn, 1906. K. Winiker. Pp. 182. (Abstract in Geol. Centralbl., IX., 2, p. 52, 1907.)

Preliminary Report on the Rossland, B. C., Mining District. By R. W. BROCK. Geol. Survey of Canada, No. 939. 40 pages.

La provincia de Contumaza y sus asientos minerales. By F. M. SANTOLALLA. Boletin del cuerpo de ingenieros de numas del Peru. No. 38, 1906. Pp. 57, with three plates and one map.

Report on the Chibougamau Mining Region in the Northern Part of the Province of Quebec. By A. P. Low. Geol. Survey of Canada, No. 923. 60 pp., with map.

Les Richesses Minéralogiques des Montagnes de l'Estérel. Cosmos. No. 1149, 2 Février, 1907. Pp. 124–127.

La Sierra de Cordoba. Constitución geológica y productos minerales de aplicacion. By G. BODENBENDER. Anales del ministerio de agricultura, republica Argentina, Sección geología, mineralogía y minería. 2. No. 2, 1905. Pp. 150, with one geologic map and thirty photographs.

The Southern Yukon. Can. Mg. Rev. Vol. XXVIII.,No. 2, 1907. Pp. 40–41.

Ueber die erzführenden Triasschichten Westgaliziens. By F. BARTONEC. Österr. Z. f. Berg- u. Hüttenw. 1906. Pp. 645–650, 664–669, with plates XIII. and XIV.

Uber einige Erzlagerstätten der Provinz Almeria in Spanien. By F. FIRCKS. Zeit. für Prakt. Geol., 14, 1906, Hefts 5 and 7. Pp. 142–150.

GEOLOGY.

Allgemeines Berggestz für die Preussischen Staaten vom 24 Juni 1865 nebst den Preussischen Berggesetznovellen. Mit Einleitung, Erläuterungen und Sachregister. By W. WESTHOFF and W. SCHLÜTER. Berlin, 1906. Price, M. 4.

Beiträge zur Kenntnis der Fumarolentatigkeit II. By HENRICH. Zeit. angew. Chemie. Feb. 1, 1907. Pp. 179–181.

Cart géologique internationale de l'Europe, votée au congrès geologique international de Bologne, en 1881, exécutée conformément aux dècisions internationales, avec le concurs des gouvernements, sous la direction de E. BEYRICH, Hauchecorne, et Fr. BEYSCHLAG. 1:1,500,000. Lieferung 5: Sheets AVII, BVII, CVII, DVII, FIV. Berlin: D. Reimer, 1905. M. 11.75.

L'État Actuel des Recherches Géologiques Exécutées en Europe sous Patronage Officiel. By A. RENIER. Ingenieur au Corps des Mines, Ingenieur géologue. Extract of report addressed to the Minister of Industry and Labor. Chaps. VI., VII. and VIII. Annales des Mines de Belgique, tome XII., 1re livraison. Pp. 118–156. 1907. (Continued from tome XI. Pp. 271–310, and 693–719.)

Geological Sketch Map of Queensland, Showing Mineral Localities. Prepared under the supervision of B. DUNSTAN, acting Gov't Geologist. Pub. 206 of the Geol. Surv. of Queensland.

The Geology of the Zambezi around the Batoka Gorge (Rhodesia). By G. W. LAMPLUGH, F.R.S., F.G.S. **With Petrographical Notes** by H. H. THOMAS, M.A., B.Sc., F.G.S. The Mining Journal. Vol. LXXXI. Feb. 2. Pp. 151, 1907. (Abstract of the Proc. of the Geol. Soc. of London.)

Grundzüge der Gesteinskunde. I. Allgemeine Gesteinskunde als Grundlage der Geologie. By E. WEINSCHENK. Second umgearb. edition.

Pp. 228 + viii, with six plates and one hundred figures in the text. Freiberg, Herdersche Verlagsbuch., 1906. (Abstract in Geol. Centralbl., IX., 1, p. 1, 1907.)

Kalendar für Tiefbohr-Ingenieure,-Techniker,-Unternehmer und Bohrmeister. Handbuch für Berg- und Bau-Ingenieure, Geologen, Balneologen, etc. By O. URSINUS. Frankfurt a. M., Verlag des "Vulcan," 1907. Pp. 276, with a *Kalendarium* and a geologic map of Germany in *ten colored impression* (10 farbigen Druck). IV. Tiefbohreinrichtungen und Werkzeuge, pp. 54–126; V. Einige Augabe aus der Geologie, pp. 127–173.

L'histoire de la terre. By L. DE LAUNAY. Paris: E. Flammarion, Bibl. de philosophie scient., 1906. Pp. 312. Price M. 2.80. (I. L'histoire de théories géologique, p. 1. II. Principes des méthodes géologiques, p. 38. III. Les forces en jeu dans les transformations de la structure terrestre et leurs effets généraux, p. 84. IV. L'histoire de la matière terrestre, p. 97. V. L'histoire de la structure terrestre. Son évolution, p. 121. VI. L'histoire de la structure terrestre. Les récurrences, p. 172. VII. L'histoire des climats. Les variations physiques et astronomiques, p. 232. VIII. Le présent et l'avenir de la terre, p. 266. IX. L'histoire de la vie sur la terre, p. 275.)

The Structural Geology of South Africa. By DR. SANDBERG. So. Africa Mines. Dec. 22, 1906.

Uebersichtskarte der Verwallungsbezirke der Königl. Preuss. Bergbehörden und der Staatswerke der Bergverwaltung, im Auftrage Sr. Exz. des Herrn Ministers für Handel und Gewerbe bearbeitet von der Königl. Geolog. Landesanstalt und Bergakademie zu Berlin. By AMTLICK. 1 : 900,000. 2 sheets 66.5 x 85.5 cm. Farbdr. Berlin, Berliner lithogr. Institut, 1906. Price M. 10.

HYDROLOGY.

Die Aufschlüsse an den Hochquellen von Orahovica und Iskrica und die Aussichten einer Erbohrung von Trinkwasser in der Umgebung von Essek, Kroatien-Slavonien. 1906. By G. A. KOCH. Pp. 16, with one table.

Ueber die Bewegung von Grundwasser. By F. WÜNNEMANN. Jour. für Gasbeleuchtung und Wasserversorgung. Jan. 26, 1907. 9½ pp.

Composition of a Nitrogen Mineral Water at Lucan. By W. E. ADENEY. Proc. R. Irish Acad. 26, Sect. B., No. 4, 1906. Pp. 50–52.

Das erweiterte Projekt der neuen Hochquellenleitung fur die Königliche Freistadt Essek, Kroatien-Slavonien. 1906. By G. A. KOCH. Pp. 97, with 12 figures and one geologic map.

Experimentelle Untersuchungen der Trinkwasser-verhaltnisse in Schotz. Anhang zu der medizinischen Arbeit desselben verfs.: Die Typhus-

epidemie im 13 schweiz. Infanterieregiment vom Herbst, 1902. By A. ZIEGLER. Diss., Winterthur, 1904. Pp. 108–118. (Abstract in Geol. Centralbl., IX., 2, p. 65, 1907.)

L'hydrologie souterraine de la Dobroudja Bulgare. By L. DE LAUNAY. Ann. de Mines. 1906. X. Pp. 115–170, with nine figures.

The Influence of Pressure and Porosity on the Motion of Sub-Surface Water. By W. R. BALDWIN-WISEMAN, M.Sc., Assoc.M.Inst.C.E., F.G.S. Quart. Jour. Geol. Soc. Vol. LXIII., part 1. Pp. 80–105, 1907, with Plate V., three figures in the text and fourteen tables.

Die Sanierung der Städtischen Trinkwasser-Leitung in Laa a. d. Thaya, Niederösterreich. By G. A. KOCH. Pp. 14 with two figures. Wien, 1905.

MINING AND PROSPECTING.

Bodenschätze und Bergbau Kleinasiens. By C. SCHMEISSER. Zeit. f. Prakt. Geol., 14, 1906. Heft 6. Pp. 186–196, with one sketch-map in the text. (Abstract in Geol. Centralbl., IX., 1, p. 5, 1907.)

Zur Entwicklungsgeschichte des Erzbergbaues in den deutschen Rheinlanden von der Wiederaufnahme des Bergbaus nach der Völkerwanderung bis zum dreissigjährigen Kriege. By Dr.-Ing. Fr. FREISE. Zeit. f. Prakt. Geol., XV. Jahrgang, Heft 1. Pp. 1–19, 1907.

Examination of Mines. By R. G. BROWN, E.M. Can. Mg. Rev. Vol. XXVIII., No. 1. Pp. 5–8, 1907.

Illustriertes Handlexikon des Bergwesens. By K. SELBACK, conseiller intimé des mines, 1st and 2nd parts. Pp. 80. Leipzig: Carl Scholtze, éditeur. (Revised in An. des Mines de Belgique, XII., 1, pp. 180–182, 1907.)

Zur Kenntnis der Bergschläge. By PROFESSOR A. RZEHAK. Zeit. f. Prakt. Geol. XV. Jahrg., 1. Heft. Pp. 23–25, 1907.

Konstitution der Zeolithe, ihre Herstellung und technische Verwendung. By R. GANS. Jahrb. d. K. Preuss. Geolog. Landesanst. u. Bergakad. für 1906. XXVII. Pp. 63–94.

Mineralogical Survey of Ceylon. By A. K. COOMARASWAMY. Administration Report, 1905. Pp. 19, three plates, three maps, and one text-figure. Colombo, 1906. (Brief abstract in Geol. Centralbl., IX., 1, p. 6, 1907.)

Mines Inspection, Herberton, Chilligoe, Etheridge, and Croydon Districts. Queensland Gov't Mg. Jour. Dec. 29, 1906. 3½ pp.

Loi Minière du Japon. By J. M. BEL. Bull. Soc. de l'Industrie Minérale. Quatrième Série, Tome V. 1re Liv. 1906. Pp. 1313–1333.

Mining and Engineering and Miners' Guide. By H. A. GORDON. Pp. 615; illustrated. 6x9½ in.; cloth; 10s. Wellington, N. Z., 1906: John McKay, Government printer. London: Eyre and Spottiswood. (Brief review in E. and M. Jl., Vol. 83, No. 4, p. 200, Jan. 26, 1907.)

Mining Industries in the United States in 1906. By A. SELWYN-BROWN, E.M., B.Sc. The Mining Jour. Vol. LXXXI. Jan. 12, 1907. Pp. 42–43.

Mining in the Orange River Colony. (Editorial.) The Mining Jour. LXXXI., Jan. 5, 1907. Pp. 19.

Mining on Vancouver Island in 1906. B. C. Mg. Rec., Dec., 1906. 4 pp.

The Mount Lyell Mining Manual (Tasmania), 1907. By H. A. H. RUSSELL, with **Sketch Plan of the Mount Lyell Field.** 1s. London: Effingham Wilson.

Prospecting with Churn Drills. By F. S. PHEBY. Can. Mg. Rev. Vol. XXVIII. No. 1, 1907. Pp. 11–12.

The Prospector's Handbook. By J. W. ANDERSON, M.A. (Cantab.), F.R.G.S. Eleventh edition. 4s. 6d. London: Crosby Lockwood and Son.

OFFICIAL REPORTS.

Geological Survey of Canada, Section of Mines, Annual Report, 1904. By E. D. INGALL, Chief of Section. Pp. 162. 6½x10 in.; paper. Ottawa, Canada; Public Printer.

L'industrie minerale del Belgio nel 1905. By L. DEJARDIN. Rassegna Mineraria, Feb. 1, 1907. 1½ pp.

New Zealand Minerals and Mining. Statement by the Minister of Mines; Report on the Goldfields; Report on Coal Mines; States of Coal Mines. Wellington, N. Z.: Department of Mines.

Preliminary Report on Black Ridge, Clermont, Queensland, with Appendices on the State of the Mineral Industry in the Clermont District during 1904. By L. C. BALL. Pub. No. 201 of the Geol. Surv. of Queensland. Pp. 141; illustrated. 6x9½ in.; paper. Brisbane, 1906. George Arthur Vaughn, Gov't Printer.

Report of the Chief Inspector of Mines in India, Under the Indian Mines Act (VIII. of 1901) for the Year Ending Dec. 31, 1905. By W. H. PICKERING, Chief Inspector of Mines. Pp. 67. 8½x13 in.; board covers. 12 annas or 1s. 2d. Calcutta, 1906: Office of the Superintendent of Government Printing.

Les richesses minérales de l'Algérie et de la Tunisie. By P.-F. CHALON, ingénieur-conseil pour les mines. One Vol. in 8°. Pp. 108, with one map outside of text. Price fr. 4–50. H. Dunod and E. Pinat, éditeurs, quai des Grands-Augustins, Paris, VI°. (Reviewed in Ann. des Mines de Belgique, XII., 1, p. 184.)

ORE GENESIS.

Einteilung der Erzlagerstätten und kurze Darstellung der Theorien über die Enstehung von Erzgängen. By A. SCHIERL. XXII. Jahresber. d.

Landes-Oberrealschule in Mähr.-Ostrau für das Schuljahr 1904–5. Pp. iii.–xiii. (Short abstract in Geol. Centralbl., IX., 2, p. 50, 1907.)

Die Erzlagerstätten. By A. W. STELZNER and A. BERGEAT. II. Hälfte. 2. Abteilung. Leipzig, 1906. 89 Abbild. Two plates.

La Genèse des gisements metallifères et des roches eruptives. By P. F. CHALON. Paris, 1906. 233–236, with six figures in the text. (Abstract in Geol. Centralbl., IX., 1, p. 3, 1907.)

Magmatic Waters. By H. W. HIXON. The Mining Jour. Vol. LXXXI. Jan. 5, 1907. Pp. 7.

Ore-Deposits and Their Distribution in Depth. By J. W. GREGORY, D.Sc., F.R.S. New Zealand Mines Record. Vol. X. Pp. 38–40, 1906. (Concluded from page 531, Vol. IX.)

Thermal Activity in Its Relation to the Genesis of Certain Metalliferous Veins. By J. PARKS, F.G.S., Director Otago University School of Mines. New Zealand Mines Record. Vol. X., No. 2. Pp. 59–62, 1906. (Continued from page 515, Vol. IX.)

PETROLOGY.

Einige Diabase des Jaschkengebirges und ihre Kontaktgesteine. By J. GRÄNZER. Tschermaks Min. u. Petr. Mitt., N. Folge, 25, 1906. H ⅓ (Tschermakheft). Pp. 61–78. (Abstract in Geol. Centralbl., IX., 1, p. 2, 1907.)

Ergebnisse petrographischer Studien an Eruptivgesteinen und kontaktmetamorphen Sedimenten aus dem rheinpfälzischen Gebiete zwischen Glau und Lauter. By E. DÜLL. Geognost. Jahresb. 17, 1906. Pp. 235–247.

UNCLASSIFIED.

Annual Review of Mining in British Columbia. By E. JACOBS. B. C. Mg. Rec. Dec., 1906. 8½ pp.

Berg-, Hütten- und Salinenwesen im Altai. By F. THIESS. Oesterr. Zeit. f. Berg. u. Hütt. 54, 1906. Pp. 598–600, with one sketch-map in the text.

British Columbia in 1906. By A. WHEELER, JR. Can. Mg. Rev. Vol. XXVIII., No. 2. Pp. 49–54, 1907. (To be continued.)

Mesure géothermiques entrepises dans le bassin du Pas de Calais pour la période 1903–1906. By LEPRINCE-RINGUET. Soc. de l'Ind. Min. Comptes Rendus Mens. 1907. Pp. 14–20.

The Metals in 1906. The Mining Journal. Vol. LXXXI., Jan. 26. Pp. 125–126; Feb. 2, pp. 159–160, 1907.

Note sur L'École des Mines de Madrid et L'École D'Ingénieurs Industriels de Bilboa. By MM. NICOU and SCHLUMBERGER, Ingénieurs au Corps des Mines. Annales des Mines, tome X., 10e liv. Pp. 403–431, 1906.

A Review of Mining Operations in the State of South Australia during the Year Ended June 30th, 1906. Issued by T. DUFFIELD, Sec'y for Mines, under the authority of the Minister of Mines. Pp. 29. Adelaide, 1906. C. E. Bristow, Gov't Printer.

Le Service géologique de Belgique. Son but, son organisation, ses résultats. By M. MOURLON. Ann Soc. Géol. de Belgique. Tome XXXIII., Mém., 1906. Pp. 85–104, with Plates I–IV.

SCIENTIFIC NOTES AND NEWS[1]

THE WELCOME NEWS has come from Brazil that geological work is to be resumed by a national survey with Dr. Orville A. Derby at its head. A new President has recently taken office. He is Dr. Alfonso Augusto y Moreira Penna, one of Brazil's most progressive statesmen, and one who bids fair to accomplish much for the promotion of science in the great Republic. From the state of Bahia he has summoned its former Secretary of Agriculture, Dr. Miguel Calmon du Pin e Almeida to assume the portfolio of Industry, Highways and Public Works. One of Dr. Calmon's first steps was the inauguration of a Geological Survey to whose direction he called Dr. Derby. Dr. Derby has brought around him those Brazilian and foreign geologists who have made valuable contributions regarding the country. The new department is called *Servico Geologico e Mineralogico do Brazil*. The headquarters will be in Rio Janeiro. A rapid general survey of the country will first be made. Detailed investigation will follow of those districts which offer special inducements because of their mineral wealth, deficiencies of water supply, or other considerations. Owing to the lack of proper topographic maps, systematic and detailed areal work will not be attempted for the present.

PROFESSOR WILLIAM OTIS CROSBY, at the Massachusetts Institute of Technology, will become in October the first professor at that institution to win the distinction of retirement under the Carnegie Foundation for Advancement of Teaching. After over thirty years of successful teaching, Professor Crosby will be able to give his time wholly to investigation and writing, and

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

to the extension of his large practice as private expert. He will retain his office and laboratory in the Department of Geology.

DR. REGINALD ALDWORTH DALY has been appointed Professor of Physical Geology at the Massachusetts Institute of Technology, the appointment to take effect October 1st, 1907. Professor Daly has completed six seasons of field work as geologist of Boundary Surveys at Ottawa. He has only the office work to finish. In Boston he will teach dynamical and physiographical geology to classes of mining and civil engineering students. He will also offer research courses in the physical geology of the igneous rocks and in oceanography.

DR. DALY'S coming to Boston is part of a movement at the Massachusetts Institute to establish a Research Laboratory of Physical Geology, directed by T. A. Jaggar, Jr. Funds for the purchase, installation and maintenance of seismographic apparatus have been subscribed. The laboratory will deal primarily with the direct measurement and record of earth movements and processes. Professor Jaggar will inaugurate the research work of the laboratory by an expedition leaving Seattle in April, 1907, to explore the Aleutian Islands. The exploration is financed by Boston men. The scientific party will number five or six, and include Professor Jaggar as geologist, Professor H. V. Gummere of the Drexel Institute as astronomer, probably a physician, a mining engineer, and two student assistants. The main object of the scientific work will be a study of Aleutian volcanos, and some attention will be given to magnetism. Travel will be by schooner from Unalaska to Attu and return. The volcano on Akutan was reported active about March 15th, and a new extension of Bogoslof rose from the sea in 1906, according to authentic reports.

GEORGE A. LAIRD, Superintendent of the Copper Queen Consolidated Mining Company's Sierra de Cobre Mines, at Cananea, Sonora, Mexico, and formerly Manager of La Victoria y Anexas, San Pedro, S. L. P., Mexico, has resigned his position with the Phelps-Dodge Company and will enter into the General Engineering business with Franklin W. Smith, of Franklin W. Smith and Company, Bisbee, Arizona.

MR. A. P. LOW, director of the Canadian Geological Survey has been critically ill at his home in Ottawa. We learn with pleasure that he has now recovered and is again able to resume his duties.

THE ANNUAL MEETING of the Canadian Mining Institute was held in Toronto on March 6th, 7th and 8th. This meeting is of unusual interest as some of the papers there presented were of exceptional interest.

THE NEW HEARST MINING BUILDING erected by Mrs. George Hearst in honor of her husband has now been deeded to the University of California. The building is the most complete building devoted to mining in any educational institution in the world. With all equipment it has cost more than $1,000,000.

F. J. POPE is now in Chile on examination work for the Guggenheim Exploration Co.

PROFESSOR CHARLES PALACHE, of Harvard University, delivered in February a course of six lectures in the Geological Department of the University of Wisconsin on the subject: "Recent Developments in the Study of Crystals."

THE LEGISLATURE has extended the field of the State Geological Survey of Michigan to cover a biological survey.

THE MICHIGAN GEOLOGICAL SURVEY has an elaborate report on peat, both in its botanical and geological aspects, by Professor C. A. Davis, in the press. The price has not yet been fixed.

THE ANNUAL REPORT of the State Geologist of Michigan has been published by the "Michigan Miner," as has often been the case, in advance of its publication by the state. This does not, however, include the longer scientific papers.

DURING THE YEAR 1906 the Kansas State Geological Survey devoted its energies principally to an investigation of the Kansas and Indian Territory oil and gas field. By legislative requirement a lithographic geological map of the state is to be prepared also and included in the forthcoming report on oil and gas which will constitute Volume IX of the State Survey reports. This report is well along towards completion and probably will go to the printer in the near future.

In connection with the above mentioned work a great many chemical analyses were made on Kansas petroleum by Professor F. W. Bushong and an extended series of tests for determining the heat of combustion was made under the direction of Professor A. P. Walker of the Department of Mechanical Engineering of the University of Kansas. Also, many analyses of Kansas natural gas were made by Professor Cady and Professor McFarland of the Chemistry Department, University of Kansas. Each series of analyses showed that products vary greatly in different parts of the field. This is more noticeable with oil than with gas, although the most extreme variation was found in natural gas.

The rare elements helium and argon were found in the gas in very appreciable quantities. This very interesting discovery led to an examination of gas from Indiana, Ohio, Pennsylvania, West Virginia and a number of other localities, every sample of which contained helium.

THE ANNUAL MEETING of the alumni of the Royal School of Mines, resident in South Africa, was held in Johnnesburg Transvaal, October 13th, 1906, U. P. Swinburne presiding. There were forty-two graduates present and a number of interesting speeches were made.

EZEQUIEL ORDONEZ has resigned his position as sub-director of the Geological Institute of Mexico and is now practicing as mining geologist at Mexico City.

DR. F. H. HATCH has recently returned from a trip to Siberia where he has been examining gold properties.

A PARTY OF SCIENTISTS has recently been organized to explore the copper, iron, coal and other mineral resources and to investigate the rubber and timber of the Congo Free State for the Guggenheim Exploration Company. The expedition sailed for Africa about April 15.

The three geologists who will make the trip are Sydney H. Ball, Millard K. Shaler, and Edson S. Bastin, all of whom have secured indefinite leave of absence from the United States Geo-

logical Survey. Mr. Ball will have charge of the scientific staff which will include R. B. Oliver, a topographer of the U. S. Geological Survey, a botanist now employed at the Bronx Park, and a St. Louis physician.

The Congo Free State is practically a virgin field so far as discoveries of valuable mineral deposits go. It is known that iron and copper exist in more or less generous quantities in the area to be explored. Traces of gold and some coal have also been found. There is reason to believe that this field offers great opportunities for the development of valuable mines. The geologists have a large area to cover and a comparatively short time to devote to the work—about a year—consequently they will do only exploratory work.

AN ILLINOIS STATE ACADEMY OF SCIENCES has been established in Illinois, which it is hoped will aid scientific work throughout the state by banding together the leaders in the various departments of science, by stimulating students in the more isolated communities, and by forming a center for all scientific interests.

The demand for such an organization is great and the opportunity promising. It is hoped that every leader and every worker in science in the state will help the cause by becoming a charter member.

Those interested are invited to correspond with A. R. Crooke, Northwestern University, Evanston, Ill., suggesting the best time for the first meeting.

DR. GEORGE OTIS SMITH has been appointed director of the U. S. Geological Survey to fill the vacancy caused by the election of Dr. Charles D. Wolcott to the secretaryship of the Smithsonian Institution. Dr. Smith received the bachelor of arts degree from Colby College in 1893, and the doctorate of philosophy from the Johns Hopkins University in 1896 in which year he was appointed assistant geologist to the Geological Survey, being made geologist in 1901. He has had charge of the geological work in New England, and is now geologist in charge of petrology. Dr. Smith will enter upon the duties of his office

with the cordial good-will and confidence of geologists and scientific men throughout the country. We wish him all success in this responsible and important position.

PROFESSOR W. M. DAVIS, of the department of geology and geography and dean of the graduate school, represented Harvard University at the dedication of the new building of the Carnegie Institute in Pittsburg.

THE SUM OF $80,000 was appropriated by the last Congress for the continuation of the investigations of the mineral resources of Alaska. Plans are being made by A. H. Brooks, geologist in charge of that work, for a busy season.

A CONFERENCE OF GEOLOGISTS who have worked on the Pacific coast of Alaska will be held in Washington, D. C., in April. The purpose of the meeting will be to compare the stratigraphy of the coastal region from Cross Sound to Cook Inlet. Besides the geologists on the Geological Survey, Professors Tarr of Cornell, Atwood of Chicago, and Grant of Northwestern University will be in attendance.

FRANK L. HESS of the U. S. Geological Survey returned the first of March from a four months reconnaissance trip through several of the western states. He investigated the gypsum deposits of California, tin deposits of California and Texas, and visited the sources of magnesite and steel-hardening metals in Colorado, Utah, California, Arizona, and Texas. Among the interesting features of the trip was a visit to the chrysoprase mines near Porterville, California.

F. C. SCHRADER, of the U. S. Geological Survey, returned to Washington early in March after spending several months in a reconnaissance of the mineral deposits of northwestern Arizona. The district is being actively developed and is receiving the attention of prospectors from Tonopah, Rhyolite, and Bullfrog. Indications are that the country merits more attention than it is getting at present. The metalliferous deposits are in two classes of rocks. In the Grand Wash cliffs pre-Cambrian rocks and associated intrusives carry zinc, lead, copper, gold and silver, while

on the west side of the region paralleling the Colorado the deposits are all gold and are found in volcanic rocks.

MESSRS. M. L. FULLER and F. G. CLAPP of the U. S. Geological Survey spent the month of March in a pleasure trip around the Caribbean sea, touching at Mt. Pélé, Trinidad, Caracas, Panama, and at several points in Cuba.

W. H. EMMONS has recently completed the mapping of the geology of the Bullfrog Special area at Bullfrog, Nevada, and returned to the office of the Geological Survey at Washington.

W. C. MENDENHALL, who has had charge of hydrologic investigations in the west coast states for the past four years with headquarters in Los Angeles, was in Washington in March to arrange plans for further work of this character the coming season. The Geological Survey proposes to continue these investigations in California, Oregon and Washington this season under Mr. Mendenhall's direction. He describes the changes brought about by the Colorado River pouring into Salten Sea as one of the most sensational episodes in the history of geographic and physiographic changes within the memory of man. Earthquakes and volcanic eruptions are commonplace in comparison. The changes that took place from month to month were remarkable, but it was most striking to see the falls 40 to 50 feet high recede from one-half to three-fourth of a mile a day. Mr. Mendenhall has made frequent visits to the Imperial Valley for the purpose of noting the changes in the physiography.

E. C. ECKEL has resigned from the United States Geological Survey to take up private practice in geological and engineering investigations of cement materials and iron ores. His office is 209 Munsey Building, Washington, D. C.

F. H. NEWELL has been made Director of the Reclamation Service, which is now a separate bureau entirely apart from the Geological Survey.

o the de-

Geologi-
p around
Caracas,

ng of the
vada, and
shington

gic inves-
ears with
March to
e coming
these in-
his season
e changes
en Sea as
eographic
. Earth-
mparison.
e remark-
feet high
day. Mr.
Valley for
.

Geological
ngineering
is office is

eclamation
t from the